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WEEKLY February 27 - March 4, 2016

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Shunned theory of quantum weirdness revived

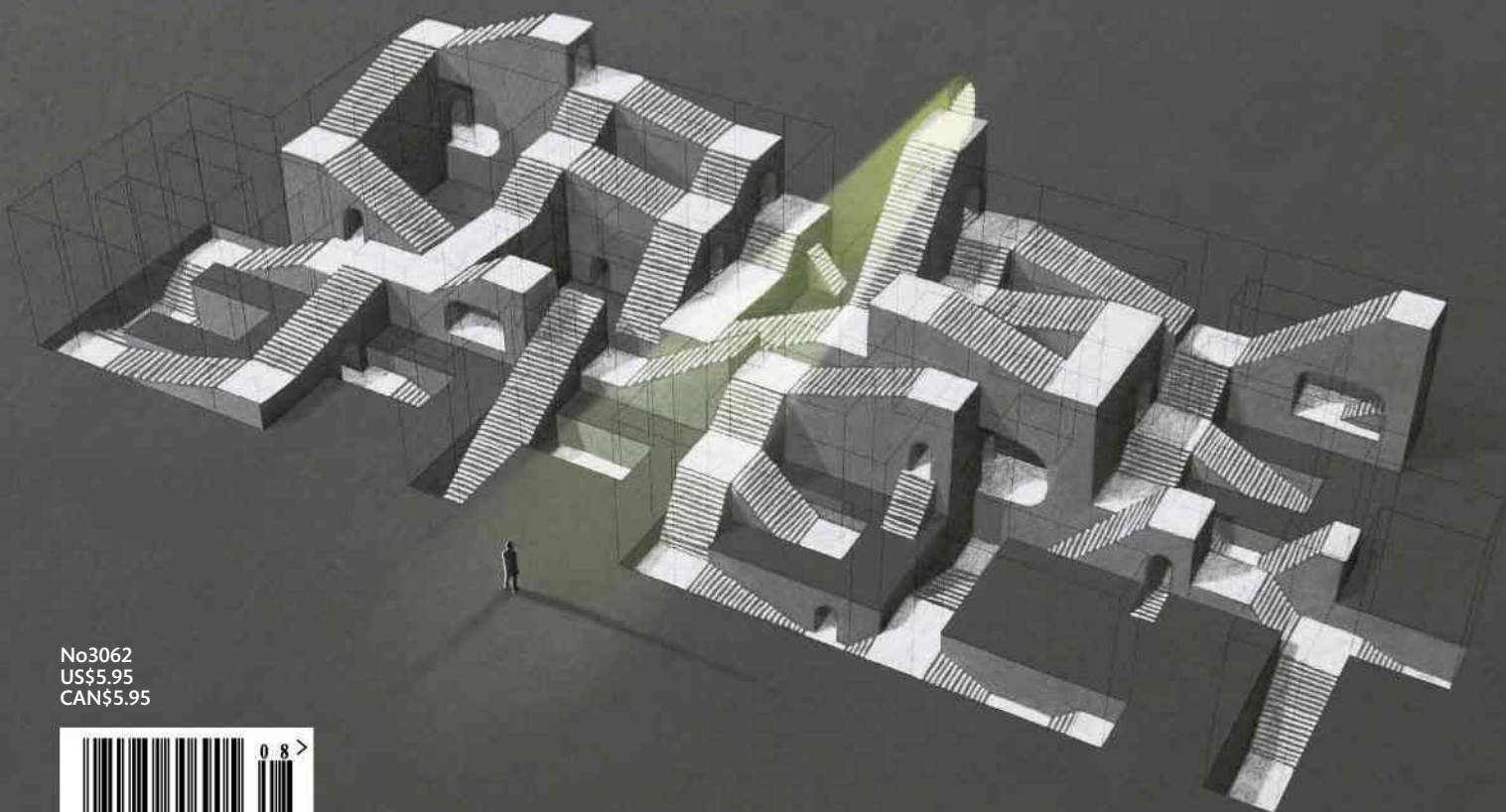
PENIS ENVY
Why human genitalia are so boring

STARVE A TUMOR
Can research back up DIY cancer diets?

WHO'S IN CHARGE? Apple, the FBI and the struggle for your data

A NEW KIND OF LOGIC

It's time to rethink the way we think



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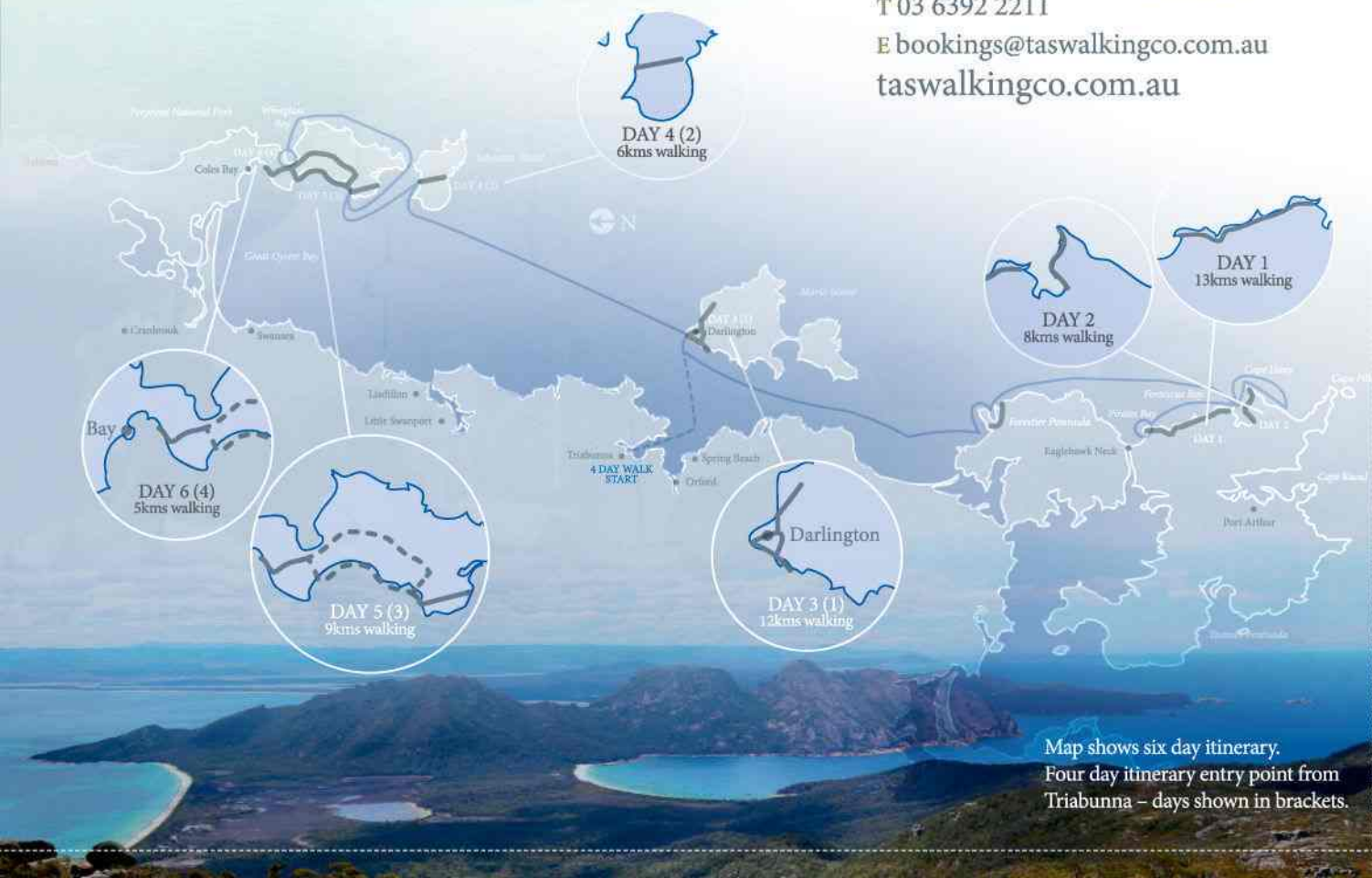
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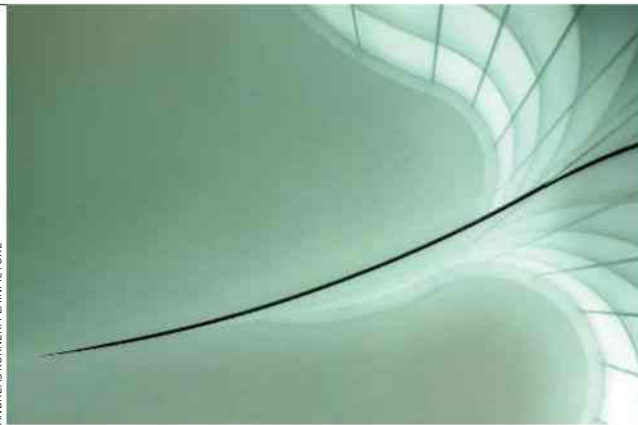
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ANDREAS KÖRNER/PLAINPICTURE



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CONTACTS

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Who's who

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General & media enquiries

enquiries@newscientist.com

Editorial

Tel 781 734 8770
news@newscientist.com
features@newscientist.com
opinion@newscientist.com

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JASON RASH

If at first you don't succeed...

Science progresses through trial and constant error

PLEASURE is not the least of reasons for doing science. As the 19th-century French physiologist Claude Bernard put it, “the joy of discovery is certainly the liveliest the mind of man can ever feel.”

Then again, Bernard also said, “those who do not know the torment of the unknown cannot have the joy of discovery”. Few who have spent much time in the lab or sharpening their theorists’ pencils would question the part torment plays in the process – not least the nagging fear that your ideas might prove irrefutably wrong.

That makes the moments of discovery all the sweeter. Before September last year no one had seen a gravitational wave, despite decades of work. The efforts of thousands of physicists mean we have them in the bag – vindicating Einstein’s idea after a century of waiting not to be wrong.

What might be next? Eyes are turning once again to the Large Hadron Collider, which switched on at close to its full design energy for the first time last year, and will start smashing particles for a new season in April. No one knows what might emerge from the debris, or what might already lurk in what we already have. A recent anomaly in LHC data from last year has prompted much excited

speculation and a storm of papers from theorists vying to explain it.

Some deride this as “ambulance chasing” – an undisciplined, anything goes, pin the tail on the donkey form of creating hypotheses. Not all those papers can possibly be right, but if in the torment of hundreds there is joy for one, there is joy for us all. This is the deal we have struck with nature: we perform experiments, occasionally catch a glimpse of

“This is the deal: we catch a glimpse of the unseen and let our imaginations run amok in response”

something never seen before, and let our imaginations run amok in response.

It is perhaps only natural to raise questions when theorists’ imaginative feats cannot readily be put to the test. String theorists, for example, play with algebra, complex geometries and knot theory, all the while hunting for results that might play into our understanding of the universe’s structure. But we cannot yet conceive experiments at the energy scales that would be required to verify the theory.

That has sparked a lively discussion about what other sources of legitimacy besides

experimental test might exist for theories that purport to be scientific (see page 38). Certainly if experimental support is not yet forthcoming, that doesn’t mean it will forever elude us. Few had any notion how to test for gravitational waves when Einstein proposed them in 1918.

And even if experiments seem to come up with the goods to support our hypotheses about how the world hangs together, it doesn’t end there: human intuitions of cause and effect prove all too often flawed (see page 34). Intuition was one reason, for example, that the de Broglie-Bohm interpretation of quantum mechanics was prematurely thrown on to the scrapheap. It has now been rescued, thanks to a new lab experiment that overturns an intuition-based thought experiment dreamed up a quarter of a century ago (see page 8). While the de Broglie-Bohm idea has not been proved right, it is certainly no longer wrong.

Not everything or everyone can be right. But perhaps the most valuable weapon science has is its ability to be wrong – and with time and patience do better. Progress might be slow, and it might not happen in the way we like. But the eventual joy is worth any amount of torment. ■



Winston was here

Fiji storm breaks records

THE records just keep tumbling. With wind speeds of nearly 300 kilometres per hour, tropical cyclone Winston was the strongest storm ever recorded in the southern hemisphere.

Winston struck Fiji last weekend. It was a category 5 storm – the highest classification.

Winston is also the second-strongest cyclone ever to strike land anywhere in terms of wind speed, according to hurricane expert Jeff Masters of Weather Underground. The strongest was supertyphoon Haiyan in 2013, which caused a devastating storm surge in the Philippines.

Fortunately for Fiji, Winston passed between the two largest islands rather than striking them directly, missing the major population centres. But in places that felt the full force

of the storm, like Koro Island, some villages have been almost entirely destroyed, according to aerial photographs. The death toll stood at 29 as *New Scientist* went to press, and is likely to rise.

Tropical cyclones derive their power from warm surface waters, and Winston was fuelled by extremely warm waters in the Pacific. This warmth is partly a result of the strong El Niño now under way, and partly a result of global warming.

As the planet gets hotter, powerful storms like Winston are expected to become more common, though there may not be more storms overall.

And it's getting hotter very rapidly at present: global temperatures in January shot up by the largest recorded monthly margin ever.

FGM controversy

IT'S controversial, to say the least. Two US gynaecologists have proposed legalising some forms of female genital mutilation. They argue this would protect girls from more extreme operations.

“The law against female genital mutilation is a marker for what is acceptable in society”

Worldwide, around 3 million girls every year undergo FGM. The practice can range from cutting genitals to removing the clitoris and labia then stitching up most of the vagina.

The practice is illegal in the UK and US, but Kavita Shah Arora and Allan Jacobs argue that attempts to clamp down on FGM haven't succeeded, and can be viewed as racist or culturally insensitive.

Instead, they suggest doctors should perform operations that they think will not affect women's ability to have children or sexual satisfaction (*Journal of Medical Ethics*, doi.org/bcqw).

“From a human rights and

healthcare perspective, it's a hard pill to swallow,” says Nawal Nour at the Brigham and Women's Hospital in Boston. “You can't say nicking a girl won't cause harm.”

Currently, women use the law to object to surgery, says Brian Earp at the Hastings Center in Garrison, New York, adding that it acts as an important marker for what is acceptable in society, regardless of issues of cultural sensitivity.

The International Federation of Gynaecology and Obstetrics has reaffirmed its zero-tolerance stance on FGM, and says it should be eliminated.

Virgin's new ride

TIME to fly again. Virgin Galactic has unveiled the latest version of SpaceShipTwo, the craft that it hopes to use to take tourists into space.

The private space flight firm says it has addressed safety issues that dogged its predecessor, which broke apart in mid-air during a rocket-powered test flight, killing one pilot and injuring another.

The new spacecraft, named VSS Unity, was revealed at a ceremony at the company's manufacturing facility at Mojave

Air and Space Port in California.

VSS Unity is designed to carry two pilots and six passengers. It resembles the first SpaceShipTwo, but with several upgrades – including a mechanism that prevents a pilot from rotating the tail stabilisers too early, the error that caused the 2014 accident.

The craft will undergo ground and flight tests at Mojave and at the Spaceport America commercial facility in New Mexico.

The next version of SpaceShipTwo after Unity is already under development.

Facebook's future

WELCOME to the future. This photo, which has been widely mocked on the internet for its dystopian look, shows Mark Zuckerberg making a surprise appearance as Samsung launched its new smartphone last week at the Mobile World Congress in Barcelona, Spain. All attendees were given Samsung VR headsets to watch the keynote address.

As well as talking up virtual reality, Facebook used the



Is this for real?

conference to announce a breakthrough in mapping. After training on just 8000 human-labelled satellite photos from a single country, its AI software scanned through billions of images of Earth taken by satellite, picking out houses and roads, to build a digital map of 20 countries in only two weeks. It analysed 21.6 million square kilometres in all. Human mappers use a similar process, but what takes them weeks took Facebook's AI seconds.

The social network wants to build a map to help plan how to deliver the internet to people who are currently offline.

Extra Ebola deaths

THE West African Ebola outbreak killed almost twice as many people as we thought, by diverting resources from illnesses such as malaria, HIV and tuberculosis.

Current figures suggest 11,316 people died from Ebola during the outbreak. But a further 10,623 people are calculated to have died from other diseases thanks to the outbreak's impact on local healthcare.

"While it's essential for resources to be targeted at a public health emergency like Ebola, it's important to consider the indirect impacts of the outbreak as well," says Martial Ndeffo-Mbah of the Yale School of Public Health, who led this analysis (*Emerging Infectious Diseases*, doi.org/bcqt).

During the outbreak, visits to health centres in some locations fell to just 10 per cent of those originally scheduled, as families remained at home to avoid infection.

The effects of that outbreak are still being felt. This week, Pauline Cafferkey, the UK nurse who has twice recovered from severe Ebola symptoms, was admitted to hospital for a third time. She contracted the virus in Sierra Leone in 2014, but it was still present in her body last October.

India joins LIGO

EINSTEIN'S handiwork is making waves across the globe. The Indian government has given initial approval for the construction of LIGO-India, a detector that will complement the US instruments that spotted gravitational waves for the first time.

The two US detectors, one in Washington and the other in Louisiana, saw the signal of a black hole merger just a few milliseconds apart, but with just two detectors the location of the source couldn't be pinned down. A third LIGO detector will allow

researchers to triangulate gravitational wave sources and train other telescopes on the same part of the sky to learn more.

The site for LIGO-India's two

"A third LIGO detector will allow researchers to triangulate gravitational wave sources"

4-kilometre laser interferometer arms is still to be decided. If funding is secured, it could be up and running by 2023. Two smaller, less-sensitive, detectors in Germany and Italy are expected to come online later this year.

Mystery wind drought hits US

GONE with the wind. The first half of last year saw the lowest average wind speeds for almost half a century across much of North America. The electricity output of US wind farms fell 6 per cent despite their capacity increasing by 9 per cent.

Now, weather watchers say the wind drought is back. "Low-wind conditions have returned to the US," says Michael Brower of AWS Truepower, a wind-power consultancy. "The possibility of a prolonged wind drought is on the minds of many in the wind industry."

So far, the wind drought hasn't had a significant impact on investment in wind plants, says Daran Rife of energy consultancy DNV GL. But he adds that "investors

naturally want to understand what happened in 2015, and what to expect in the future".

The immediate cause of the low winds last year was a large ridge of high pressure air that formed over the north-eastern Pacific and the western half of North America. This diverted wind-bringing storms far north into the Arctic. "It is the strongest in records dating back to 1960," says Rife.

The ridge could be a result of El Niño or of the Pacific Decadal Oscillation, an El Niño-like pattern of climate variability that lasts longer. In the past two years, this oscillation has switched to its "warm" phase, meaning that the wind drought could stick around through 2016.

EDYTA BLASZCZYK/ODessa AMERICAN/PPRESS ASSOCIATION IMAGES



Still air just won't cut it

60 SECONDS

Frozen ocean

It's cold out on the seas of Charon. Images recently downloaded from NASA's New Horizons probe suggest that Pluto's largest moon once had an ocean beneath the surface that has now frozen. This would explain its fractured exterior, caused by ice expanding and stretching the moon's landscapes.

Bad air

Some 40,000 people die early in the UK every year because of outdoor air pollution, according to a study by the Royal College of Physicians and the Royal College of Paediatrics and Child Health. When combined with the impact of indoor air pollution, including radon gas and second-hand smoke, the cost to the National Health Service exceeds £20 billion every year, the report suggests.

Space cadets

Want to be an astronaut? Get in line. More than 18,300 people have applied to join NASA's next class of spacefarers, smashing a record of 8000 in 1978. The agency will announce the select few - between eight and 14 - who make the cut next year. Those chosen could be among the first to fly on a US spacecraft since the space shuttle was retired in 2011.

Lice to meet you

New world monkeys have humans to thank for their parasites. Genetic analysis of lice from howler monkeys shows they were originally human lice, but switched host when the first humans reached the Americas (*Infection, Genetics and Evolution*, doi.org/bcqy).

Shark-saving pact

A total of 40 countries have agreed to extend the list of protected shark and ray species from seven to 29, under the global Convention on Migratory Species. The countries are now obliged to take practical steps to protect those species, which include great whites, whale sharks, hammerheads and devil rays.

Quantum hides orderly reality

An experiment brings a neglected theory back into the fold, says **Anil Ananthaswamy**

TIME for a reality check? A reboot of a classic quantum experiment suggests that particles follow well-defined trajectories, something denied by standard quantum theory. If it holds up, it might lend support to Einstein's claim that "God does not play dice with the universe" – but in a way Einstein himself would have hated.

The behaviour of the quantum world has befuddled physicists for nearly a century. "We have had geniuses working on it and we still have a problem," says Basil Hiley, a quantum physicist at Birkbeck, University of London.

Unlike the classical world, with its clockwork precision and pleasing predictability, the quantum world is rife with randomness. The famous illustration is the double-slit experiment (see "Quantum Zoo", below), with its weird results. What this experiment means depends on how you

interpret quantum mechanics.

In 1952, David Bohm suggested that the only reason the quantum world appears weird is because we don't know enough about its underlying reality. Beneath the quantum weirdness, he said, reality is orderly, and everything depends on everything else. In his universe, something happening in a distant galaxy is influencing you right now and vice versa.

Take the debate over whether

"In Bohm's universe, something happening in a distant galaxy is influencing you right now"

a photon is a wave or a particle. According to Bohm it is both: a photon is a particle with a definite trajectory governed by a wave on which the photon rides. The wave can be influenced by other particles, which in turn changes the trajectory of the photon.

ANDREAS KÖRNER/PLAINPICTURE



This "Bohmian mechanics" did not go down well with everyone. A 1992 thought experiment seemed to sound the death knell. Dubbed the ESSW experiment after the initials of its four authors, it revisited, with Bohm in mind, the double-slit experiment, in which

photons are fired at two slits.

Bohm held that a photon will go through the top or the bottom slit, not both. Guided by their waves, the top ones should always end up at the top half of a screen on the other side and the bottom ones at the bottom half.

The ESSW experiment added a twist. The researchers imagined a detector in front of the slits that could tell whether a photon went through the top or bottom one. Their analysis showed something very strange: a photon could trigger the top-slit detector, but end up at the bottom half of the screen. They called this path a "surreal" trajectory.

Bohm is back

Now Aephraim Steinberg of the University of Toronto in Canada and his colleagues have performed the ESSW experiment themselves – and concluded that Bohm is back in the game

QUANTUM ZOO

The famous double-slit experiment contains "all of the mystery of quantum mechanics", in the words of physicist Richard Feynman. Imagining how it works illustrates three competing quantum theories.

The experiment involves firing photons at two slits. Intuition tells us that each particle should pass through one slit and make a single mark on a screen on the other side.

Instead, you get an interference pattern of light and dark bands on the screen, as if each photon behaved like a wave and passed through both slits simultaneously. Is the photon

a particle or a wave? Depends on your point of view.

According to the Copenhagen interpretation, the question is meaningless until you make a measurement. If you use a detector to see which slit the photon went through, it acts as a particle. Otherwise, it behaves like a wave.

In the many-worlds interpretation, all possible outcomes of a quantum system exist, but in different worlds, or realities. The photon takes all possible paths, each in a different world. These worlds interact to give rise to the interference pattern. But

put a detector at one of the slits and you split reality in such a way that the worlds cannot interact, so the interference pattern disappears.

Bohmian mechanics argues that a photon is both a wave and a particle. The wave guides the particle through one or the other slit, dictating its trajectory and sending it to a specific point on the screen. Since everything affects everything in Bohmian mechanics, these photon trajectories bunch up in ways that give rise to the interference pattern. Putting a detector at one of the slits changes trajectories, destroying the pattern.

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A well-defined path?

(*Science*, doi.org/bcqq).

They started with pairs of entangled photons, which are so intimately related that measuring the polarisation of one affects the polarisation of the other, however far apart they are. One of each pair was sent into a device analogous to the double-slit set-up.

Depending on whether its polarisation was vertical or horizontal, the photon was steered towards either the top or bottom slit. As it negotiated the apparatus, the researchers measured the photon's position gently enough to preserve its quantum nature. Doing this 25,000 times a second gave them one measure of the trajectories of the photons.

The other photon of each pair stayed outside the apparatus, acting as a probe – analogous to the detector in the ESSW experiment. Because they are entangled, the probe's polarisation should dutifully reflect the slit its

partner took, acting as another measure of its path. And indeed, at the start, the probe photon's polarisation mirrored the path of its partner.

The team kept measuring the probe's state as its partner travelled, and found that the polarisation kept changing. By the time the partner reached the screen, the probe photon was in a superposition of both states, equally likely to be horizontally or vertically polarised.

The team thinks this means that the trajectory of the travelling photon changed the probe's polarisation – in line with Bohm's ideas on non-local interactions. Einstein would be relieved by the determinism, but not the non-locality.

This could resolve ESSW's problem with Bohm: they thought the problem lay with the photon's trajectory, but Steinberg and his colleagues showed that the trajectory is real. The detector and the probe are just unreliable witnesses.

"I'm happy to see this resolution. It restores my taste for Bohmian mechanics," says Steinberg. "We want to bring it back to its rightful place among all other interpretations."

Hiley, who worked with Bohm until his death in 1992, is impressed. "It is a new way of looking at quantum non-locality, which vindicates the Bohm position," he says.

Sheldon Goldstein, who studies the foundations of quantum mechanics at Rutgers University in New Jersey, points out that the experiment's observation of particle trajectories can also be explained using other theories.

But Goldstein says there are changes afoot. "People are taking Bohmian mechanics a little bit more seriously," he says. "There was a time when you couldn't even talk about it because it was heretical. It probably still is the kiss of death for a physics career to be actually working on Bohm, but maybe that's changing." ■

Fear of predators can alter entire ecosystems

TRY telling raccoons that barking dogs don't bite. The fear of large carnivores, such as dogs, can have knock-on effects throughout an ecosystem.

Predators don't control populations of their prey just by killing them. They also paint what is termed a landscape of fear, inhibiting prey from feeding and turning parts of their habitat into

the intertidal areas, and in turn, to a decline in numbers of those animals' prey and competitors (*Nature Communications*, DOI: 10.1038/ncomms10698).

For red rock crabs, for example, this effect must be due to changes in their behaviour, since reproduction takes at least a year. The crabs move from subtidal into intertidal areas to forage, but avoid regions where they detect chemicals released by dead crabs. With raccoons foraging less, these chemical cues decreased and crabs entered the intertidal zone more.

It is the first experimental demonstration of how the effects of fear cascade through an ecosystem, says John Laundre at the University of California, Riverside. "We're just beginning to understand these multilevel facets that can occur," says Laundre, who originated the use of the phrase "landscape of fear" in ecology.

To understand how the presence of large carnivores keep herbivores and smaller predators in check and so protect biodiversity is critical, says Suraci. "We've succeeded in wiping out large carnivores in most of the globe, and we're only now beginning to understand the ecological consequences," he says. "The real message here is that we need large carnivores." Sam Wong ■

"The sound of barking dogs cut raccoons' foraging time by 66 per cent and boosted the numbers of their prey"

no-go zones. Now it appears that this has far-reaching effects throughout the food web.

Domestic dogs are the main predators of raccoons on the Gulf Islands of British Columbia, Canada. Justin Suraci and his colleagues at the University of Victoria in Canada wondered what would happen if they stoked the raccoons' fear of dogs without increasing predation. They set up speakers along the shoreline on two islands and played either the calls of dogs, or of seals and sea lions, which also live here but are not a threat to raccoons.

The dog sounds cut the raccoons' foraging time by 66 per cent over the course of a month. They also led to a rise in the abundance of crabs, fish and worms that raccoons feed on in



SHANNA BAKER / HAKAI MAGAZINE

Woofing ruins my appetite

A diet to starve brain cancer

Can science find a way to test alternative disease treatments, asks **Hal Hodson**

THE late morning train was packed. Andrew Scarborough had been feeling odd recently – headaches would come and go, leaving him slurring his words. He blamed the stress of his master's degree. The flu, perhaps.

Pain unfurled in his head as the train pulled south from London. Spasm gripped his face and his throat seized up. He started to yelp uncontrollably. "I felt like I was

going to die," he says. Then he slithered off his seat onto the floor of the carriage, unconscious.

It wasn't flu. Scarborough collapsed because vessels in an undiagnosed tumour had burst, spreading blood and cancerous cells through his brain. Once he had recovered from the aneurysm, he started down the usual path: surgery, followed by chemotherapy and radiotherapy.

This is the "gold standard" treatment for aggressive brain cancer. There's only one problem, says Matt Williams, a clinical oncologist at Charing Cross Hospital in London: "It doesn't work." Williams means that brain cancer patients still die: they just gain, on average, an extra 15 months. "We've made very little progress. The last significant advance was the addition of

chemotherapy to radiotherapy – in 2005," says Williams. Candidate drugs have failed in clinical trials, and there's little hope that any will be found in the near future.

Like others in his position, Scarborough quickly realised that his prognosis was bleak and turned to the internet for alternatives. He read peer-reviewed scientific papers that seemed relevant to his condition, albeit about studies done on mice or on cells in Petri dishes, not humans, and he came up with a plan. Having studied nutrition at university, his starting point was a food plan known as the ketogenic diet, which involves cutting back on carbohydrates and increasing fat intake (see "Cake out, insects in", right).

The medical establishment tends to disapprove of self-imposed diets to control cancer, and for good reason. Apricot kernels and coffee enemas, pills made of kelp and clover: the web is awash with alternative cancer therapies, most of them with no

"The last big advance in treating brain tumours was the addition of chemo to radiotherapy - in 2005"

scientific basis whatsoever. Many could be dangerous for people already debilitated by cancer.

What makes Scarborough's approach noteworthy is that some oncologists think the basic idea is worth exploring. Adrienne Scheck is running a study at the Barrow Neurological Institute in Phoenix, Arizona, in which people who have been newly diagnosed with brain cancer are put on a ketogenic diet that contains four parts fat to one part of protein or carbohydrate,

DAVE STOCK



Andrew Scarborough was diagnosed with cancer aged 27

and stay on it through their radiation and chemotherapy.

Our cells usually get their energy from glucose, which comes from the carbohydrates we eat. But when these aren't available, the liver breaks down fat into fatty acids and chemicals called ketones, which our cells can burn for energy instead. Cancerous cells are particularly glucose-hungry and, unlike other cells, don't have the ability to switch fuel sources. Scarborough knew that a ketogenic diet is sometimes helpful for the management of epilepsy, because one of the breakdown products of fat binds to brain cells, calming the electrical activity that triggers seizures. He hoped his version would deprive the tumour of the glucose it needed, starving it into submission.

You bet your life

Three years later, the remnants of Scarborough's tumour that survived the standard therapy have all but disappeared. That striking outcome has surprised his doctors but it is impossible for anyone to know what his experience tells us. He might have responded unusually well to the conventional treatment, with the ketogenic diet having been irrelevant or actually harmful to his overall health. Scarborough would occasionally have seizures, an after-effect of the aneurysm, if he miscalculated his nutrient balance: it took trial and error to find what seemed a stable approach.

If the diet did have any effect, that would have to be pinned down, along with the risks, before doctors could suggest it (or more likely a less extreme version) to other people with similar conditions. And because no one knows if it made any difference, Scarborough has no greater assurance that the cancer won't return than anyone else in remission.



But if the ketogenic approach is promising, why has it been left to people like Scarborough to cobble together a diet without any real idea of whether it will work? Part of the problem is that there is no commercial incentive to pursue it: drug companies can't afford to conduct trials that cost hundreds of millions of pounds to prove the efficacy of a treatment that anyone can get for themselves at the local supermarket. And there is no accepted way for showing efficacy of a treatment other than trials.

CAKE OUT, INSECTS IN

Andrew Scarborough's self-designed version of the high-fat, low-carb ketogenic diet is pretty extreme. As he tries to starve his cancerous cells of food, he eats less than a gram of carbohydrate a day. Instead, he eats a lot of oily fish, animal fats and insect flour. "To make sure I didn't have any micronutrient deficiencies, I started to include nutrient-dense organ meats and the insects," he says. Buying kilos of lamb's hearts and brain from the butcher, or going online to order crickets sold as snake food became the norm for him.

Now two studies aim to test the ability of such a diet to help treat cancer (see main story). To do this, the researchers have to work out how to give a version of this diet to people who are undergoing cancer

treatment and already struggling with a dramatic lifestyle change. The nature of the intervention also stands in the way of doing a traditional clinical trial. For example, the status quo is a randomised double blind trial, in which people are put into groups at random and neither they nor researchers know who is having the treatment and who is having a placebo. The ketogenic trials could never be double blinded because the change to the participants' diet would be impossible to hide. Nor can it be randomised because people need to agree to make drastic lifestyle changes.

Some, like Scheck, are investigating its potential anyway. Williams, inspired by the same body of literature of case reports as Scarborough, is designing a trial to offer the ketogenic diet to between 40 and 80 people with brain cancer over the next two years and track their progress.

Neither study will be able to confirm whether adhering to the ketogenic diet for the long term will extend life by more than 15 months, but they may offer useful insights. For example, Williams's study will be tracking how chemicals and metabolites in participants' blood respond to the

treatment and already struggling with a dramatic lifestyle change.

However you do it, keto isn't easy. The idea is to make cells survive off ketones generated from fat, rather than glucose from carbohydrate. A single slice of bread can knock the body back to glucose. "It's about reconfiguring all the food in your house. Changing personal behaviour is much harder than taking a drug," says Matt Williams at Charing Cross Hospital in London, who is carrying out one of the trials.

He envisions specially designed ready meals. "I have to say to people: if being on the ketogenic diet isn't effective, you're still going to die of your brain tumour, and all I've done is I've deprived you of cake - for the last year of your life," he says.

diet, perhaps eventually offering a way to get any benefits more directly. And both are deploying "keto" alongside the current gold-standard combination of surgery, chemotherapy and radiotherapy. "I think the most bang for the buck is using it to make those therapies better," says Scheck.

If the initial results are promising, Scheck and Williams are planning larger follow-ups.

"Scarborough would occasionally have seizures if he miscalculated his nutrient balance"

Scheck says her study is about looking at what people are already doing to themselves, in an attempt to validate methods that seem to work. "There is a wide variety of things people are doing: some work and some do not. A trial must have enough people doing the same thing to allow a conclusion to be made, otherwise it is just another collection of anecdotal studies," she says.

Halima Khan of the Health Lab at Nesta, a charity that supports innovation, says the way medical interventions are validated will need to change. It's becoming more widely recognised that traditional clinical trial methods will need to be adapted to enable patient-generated data to be gathered and analysed for clinical research.

Whether or not this happens, those who feel they have little to lose by trying alternative approaches are increasingly likely to find or devise their own treatments, even if the benefits are unknowable and the potential dangers enormous. "I was willing to take a lot of risks at that time, even risking my life," says Scarborough, who plans to continue with his diet.

Unless we can find a way to test approaches that don't fit into the traditional mould, people like Scarborough will be left needing to gamble with their lives to see if a treatment works. ■

Stalking the radio blasts from the sky

Jacob Aron

A MYSTERIOUS blast of radio waves has been traced to its source for the first time. Its origins suggest there are multiple causes of these signals, which have been puzzling astronomers for nearly 10 years.

Fast radio bursts (FRB) are powerful but incredibly brief, so are hard to spot. The Parkes radio telescope in Australia made the first detection in 2001, but no one noticed the signal, lasting just 4.6 milliseconds, until 2007. Since then, astronomers have only found a dozen or so more, and just one – in May 2014 – was seen as it happened.

Even then, we couldn't identify the source. "When you find them you have an idea of where they are in the sky, but there are lots of galaxies so you're not really sure which one it is from," says Evan Keane at the Jodrell Bank Observatory in the UK.

In principle, though, catching an FRB in the act lets astronomers point several telescopes at it in the hope of tracking it down. Now Keane and his team have got one in their sights.

On 18 April last year, the Parkes telescope picked up a signal clocking in at under a millisecond. Keane and colleagues had set up a system to alert other telescopes of an FRB detection, and using the Australia Telescope Compact Array, they found a radio afterglow that lasted six days. Switching to the Subaru telescope

in Hawaii, they traced the signal to an elliptical galaxy around 7 billion light years from Earth.

Explanations for FRBs have ranged from pulsars to aliens. "There are probably more theories than there are fast radio bursts actually known," Keane says. But elliptical galaxies are old, so if one is the source of an FRB, you can rule out anything linked with a young stellar population, such as an outburst from a pulsar or magnetar – types of neutron star that emit periodic signals. Instead, Keane thinks the blast of energy released by two neutron

stars merging could have been the culprit in this case (*Nature*, DOI: 10.1038/nature17140).

But this type of event can't explain a 2011 FRB, recently unearthed in data from the Green Bank telescope in West Virginia. It lasted at least a millisecond, suggesting a different cause – perhaps a flare from a magnetar. And since magnetars can flare up from time to time, that suggests some FRB sources may be giving repeat performances, though no examples are known so far.

Merging neutron stars should also release gravitational waves. Two weeks ago, the team running the Laser Interferometer Gravitational-Wave Observatory announced the first detection of these waves, albeit from merging black holes. Now that LIGO's capability is proven, it could help us distinguish between different FRB sources.

"If these neutron star mergers also produce FRBs, we would expect them to coincide with LIGO detections," says Maura McLaughlin of West Virginia University in Morgantown, who was part of the teams behind the first FRB discovery and the Green Bank find. Seeing the same event with multiple telescopes provides a fuller picture, she says. "We have very little information with radio FRB measurements – all we have is one brief pulse." ■



FRBs are a tough act to follow

Bonobos expect to be treated fairly by others

HE STARTED it! Bonobos shriek when attacked. But they produce different sounds depending on whether this happens with or without provocation. This distinction adds evidence to the idea that they sense when others have treated them unfairly.

A bystander sometimes intervenes, supporting or consoling the attacked ape. This could mean that bonobos

also take into account the fairness of how others are treated, something so far thought to be limited to humans.

It suggests that the basis of fairness is probably present in bonobos, says Zanna Clay of the University of Birmingham, UK. Her team analysed over 800 hours of videos of two groups of bonobos at the Lola Ya Bonobo sanctuary in the Democratic Republic of the Congo.

When one bonobo attacks another, there is sometimes an obvious reason, such as fighting over food. On other occasions it appears unprovoked, and in those cases the scream is longer,

more high-pitched and harsher-sounding (*Journal of Comparative Psychology*, doi.org/bcp3).

"This suggests they're aware of what should and shouldn't happen to them," says Clay. "It's sort of like if someone comes up to you and slaps you in the face: your vocalisations are quite different to if you're in a rough game and you're expecting someone to slap you. So we think it taps into

"Bonobos may be aware of what should and shouldn't happen to them within their social norms"

something that we do as humans."

Shrieks in response to unprovoked attacks might be signals to the assailant to back off or cries for help. "We think these screams are actually eliciting interventions and help from third parties," says Clay. "It probably also inhibits the aggressor from doing it again."

Sarah Brosnan at Georgia State University, Atlanta, says this is the first study that demonstrates not only that individuals react to violations of social expectations, but do so in a way that may be a signal to others that a violation has occurred. Sam Wong ■



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The choice is yours...

Why people can be so easily coerced

Andy Coghlan

"I WAS simply obeying orders." It's the oldest excuse in the book, trotted out when people are accused of barbarity – including Nazi atrocities in the second world war and genocide in the Balkans.

In a modified version of a notorious experiment by Stanley Milgram, scientists have found that our brains do indeed lose a sense of control over our actions when we obey orders, explaining why people can be easily coerced.

In 1963, Milgram – played in the 2015 film *Experimenter* by Peter Sarsgaard (pictured above) – ordered study participants to deliver electric shocks to another person if they answered questions incorrectly. Unknown to them, the person they were questioning was an actor pretending to react to the shocks. Despite seeing their "victim" in apparent distress, many people obediently delivered the shocks when encouraged by an authority figure.

In a milder version of the experiment, Patrick Haggard of University College London and his colleagues have shown that people mentally distance themselves from their actions when obeying orders. The upshot, says Haggard, is that people who are following orders may feel a reduced sense of control at a basic level: "It's important because it addresses the question of autonomy and voluntariness."

The experiments were based on work showing that when

"If people obeying orders feel reduced responsibility, we must hold people giving orders to account"

people do something voluntarily, they perceive the time delay between their action and the outcome to be shorter than if they were obeying orders. A longer perceived time can therefore be used as a marker for a reduced sense of agency, or control.

The team assigned pairs of participants to the role of "victim" or "agent". Agents had to give a small electric shock to a victim's hand for a monetary reward. Half the time, agents decided whether to inflict the punishment; the other half, they were ordered to.

In all cases, agents confirmed their punishment choice by pressing on a keypad. Within the next second, the agent would hear a tone and then estimate how long in milliseconds this came after pressing the keypad. Agents consistently estimated the time lag to be shorter when they chose to punish, compared with when they were ordered to do so, suggesting they felt less responsibility for their actions when obeying orders (*Current Biology*, doi.org/bcnj).

"These are clever studies with important findings," says Stephen Reicher at the University of St Andrews, UK. "They add a new dimension to our understanding of conformity and obedience."

Haggard says the study has important implications for how we attribute blame. "If people acting under orders feel reduced responsibility, society needs to hold people who give orders more strongly to account." ■

Emissions cuts would save lives immediately

FORGET our children's future. Cutting carbon emissions is worth doing just for the immediate health benefits of lower air pollution. The value of the lives saved would vastly outstrip the implementation costs.

That's what Drew Shindell of Duke University in North Carolina and his team found when they looked at the impact of a 40 per cent cut in emissions in the US by 2030 – much larger than anything planned.

By 2030, this would prevent nearly 300,000 premature deaths and more than 30,000 a year thereafter. This is worth around \$250 billion a year, according to the valuation the US Environmental Protection Agency places on saving lives (*Nature Climate Change*, doi.org/bcqq). This does not mean there will be real savings of \$250 billion – rather, the figure reflects what people are prepared to pay to reduce their risk of dying early.

"It's a really quite large benefit that is realised pretty much immediately," Shindell says. Most analyses assume it will be decades before any benefits of cutting emissions become apparent. And the detrimental effects of air pollution are largely hidden. "People see someone die of a heart attack and don't realise there is a connection with air pollution," Shindell says.

His calculations do not take into account other potential benefits of cleaner air, such as 29,000 fewer US children per year hospitalised because of asthma attacks. This would bring real savings in healthcare costs. Other developed countries would reap similar benefits from emissions cuts, and for developing countries the number of lives saved would be even greater, Shindell says.

Air pollution could be greatly reduced without abandoning fossil fuels – but it would be extremely costly. It is more efficient to switch to renewables and electric cars than bolting on ever more pollution-reducing devices to power stations and vehicles. Michael Le Page ■



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Follow the salt to find Martian life

Shannon Hall

NEVER mind water. Martian life might be buried deep in salt.

Billions of years ago, the Red Planet hosted rivers, lakes and seas – suggesting microbial life could have thrived in the past.

“Most of my fellow scientists feel confident that there’s a very high chance that life existed at some point on Mars,” says Dirk Schulze-Makuch of Washington State University. “So the question

is only, with conditions worsening to colder and drier, whether life could have hung in.”

Schulze-Makuch and his colleague Alfonso Davila of the SETI Institute in California, investigated how microbes adapt to dryness here on Earth. Previous research in Chile’s Atacama desert (pictured) – a close Earthly analogue to Mars – has shown that many organisms can survive for years after drying out, reactivating quickly after rehydration.

Rehydration doesn’t have to come in the form of pools of water. Many microbes can live inside porous crusts of salt, which absorb moisture directly from the air – a trick Martian microbes could have used as the planet dried out.

In fact, Schulze-Makuch thinks they would have taken this leap out of evolutionary necessity. “We should never underestimate the resourcefulness of life,” he says.

Mars is between two and 50 times drier than the Atacama desert today, but that might not have always been so. Mars’s axis tilts back and forth every few hundred thousand years. At those times, the icy poles redistribute any water they contain, making

conditions more similar to the Atacama. That means life could have survived until relatively recently – and perhaps even into the present.

“We all assume that we Earthlings are so superior because we have a huge biodiversity, but we have to keep in mind, we are a water-rich planet,” says Schulze-Makuch. On a dry planet, he says, evolutionary pressures will be greater. “So it’s conceivable that indigenous Martian life could be even better at adapting to the Martian conditions.”

Currently, the search for life focuses on ancient life in wet habitats. But Schulze-Makuch and Davila think we should switch gears to look for salt deposits in dry habitats, where life could potentially exist today (*Astrobiology*, doi.org/bcqp). Such deposits have been spotted in Mars’s southern highlands.

That could happen. Briony Horgan of Purdue University in Indiana and other investigators involved with the Mars 2020 mission are deciding where to send the next rover. Their list is down to eight potential sites, two of which are dry lands that might have salt deposits.

Determining which spot is the most likely to harbour ancient life is tricky, and it’s unclear as yet which site will win overall, says Horgan. But the team still has two years to decide. ■



Salt helps Atacama microbes survive

Vaccine cuts cancer-causing infections

VACCINATION against human papilloma virus has more than halved the number of HPV infections – the leading cause of cervical cancer – in US teen girls, despite its low uptake.

Growing evidence that HPV vaccination works may convince more countries to give it to teenage boys, as HPV also causes cancers of the throat and anus, as well as genital warts.

Almost everyone who has sex without a condom will catch HPV at some point; the virus dwells in the moist mucosal tissues of the genitals and mouth and can be passed on via semen and vaginal fluids. Most people shake off the infection, but in some women it lingers, causing cervical cancer after about 20 years.

As large-scale vaccination only started a decade ago, it’s too soon to see any fall in cervical cancer rates – although studies have shown that cases of genital warts, which occur much sooner, are already falling.

The new study looked at data

collected through large health surveys performed regularly in the US. Researchers combined results from the latest two, carried out between 2009 and 2012, and found that about a third of 14 to 19-year-old girls had received all three doses of the vaccine.

These results were compared with two earlier surveys performed between 2003 and 2006, before the vaccine came in. Since it was

introduced the number of girls who had HPV in their vaginal fluid fell from 11.5 per cent to 4.3 per cent (*Pediatrics*, doi.org/bcqd).

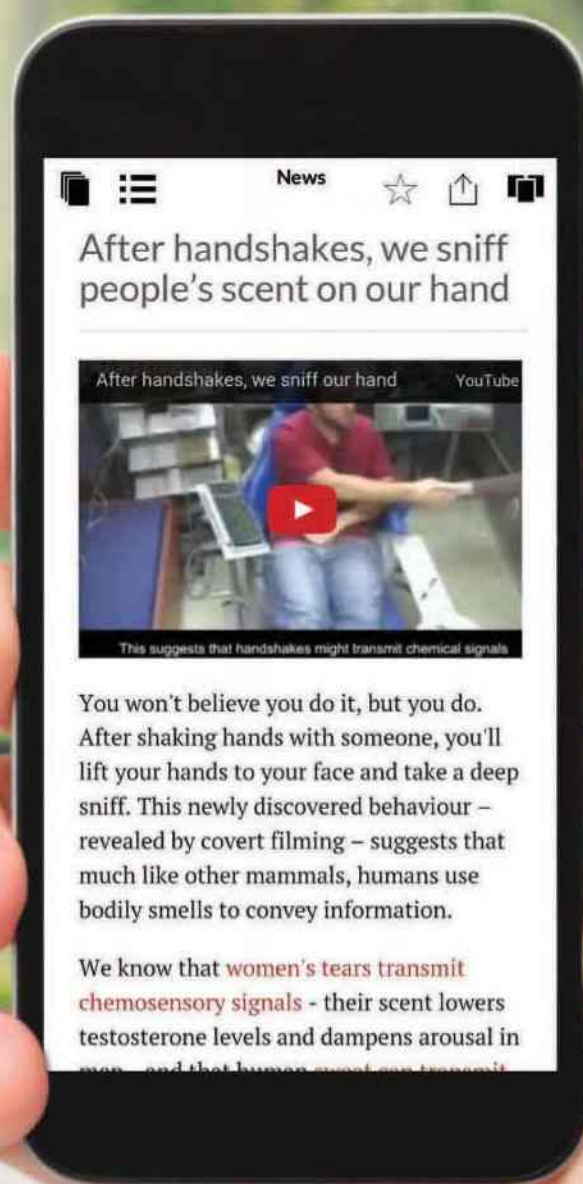
Like most vaccines in the US, uptake of the HPV shot suffers from anti-vaccine sentiment. “Showing the effectiveness may help to convince doubters,” says Johannes Bogaards of the National Institute for Public Health and the Environment at Bilthoven in the Netherlands. He thinks that while there will always be some dogmatic opposition, there is a larger group of people who are more open to argument. Clare Wilson ■

“Showing the effectiveness of a vaccine may help convince the doubters and improve uptake”

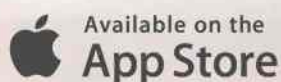
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Sea butterflies 'fly' in water just like insects do in the air

THESE graceful winged sea snails are so admired for their looks that they are known as sea butterflies. It turns out that they share more with insects than just a name – they flap their wings under water just like flies.

The tiny snails, *Limaea helicina*, are one species of zooplankton in the cold waters of the Arctic and Antarctic. Their heavy shell makes them sink like a rock when stationary – unless they secrete a mucous web that keeps them afloat. They have also evolved wing-like appendages for swimming. But exactly how they beat their “wings” and how that propels them was unknown.

Now David Murphy at Johns Hopkins University in Baltimore, Maryland, and his team have captured those details for the first time, using four high-speed cameras in a tank with free-swimming snails.

What they saw surprised them. Most zooplankton paddle to push them through the water. But sea snails flap their wings just like a fruit fly, generating lift (*Journal of Experimental Biology*, doi.org/bcnm).

“I had an ‘aha!’ moment when I saw its wing tips move in the same distinct figure-eight pattern,” says Murphy. This shows evolution converging on one locomotion technique to allow unrelated species to navigate similar environments. Due to their tiny size, the balance of inertial and viscous forces that sea snails experience in water is similar to that experienced by flies in air.

LIGO's black holes collided inside a star

CALL it a gut reaction. Space-time ripples may have come from two black holes colliding inside the belly of an enormous star.

Scientists already knew that the gravitational waves detected by LIGO, the Laser Interferometer Gravitational-Wave Observatory, were generated when two black holes merged. Just 0.4 seconds later, NASA's Fermi gamma-ray space telescope detected a bright

burst of gamma rays. It's not clear whether the same event triggered both signals, but the Fermi team calculated that the probability of a coincidence was just 0.0022.

But models of gamma-ray bursts suggest that isolated black holes can't ignite them.

Avi Loeb of Harvard University thinks he has an explanation: you could get a gamma-ray burst if the two black holes formed inside a

very massive star. Once the black holes merged, the star would collapse, triggering intense beams of gamma rays (arxiv.org/abs/1602.04735).

“The only way to explain the Fermi signal is to surround the black holes with a lot of dense material, and the obvious way to do that, as in Loeb's idea, is to put them inside a star,” says Dan Maoz of Tel Aviv University in Israel. “Maybe there are other ideas, but we need to think them up.”

Voices best for warnings in space

FIRE! Fire! Astronauts aboard the International Space Station may respond more quickly to human voice alerts than other types of emergency sounds.

ISS crew are currently notified of dangerous events such as fires with specific sound tones, but in a high-stress situation it can be difficult to remember what they mean, says Aniko Sandor at the NASA Johnson Space Center (JSC) in Houston, Texas.

To see whether voice alerts could be more useful, Sandor and her colleague Haifa Moses tested tones against voices in the Human Exploration Research Analog at the JSC, intended to simulate a real space station or planetary base.

One participant reacted to both kinds of alert at similar speeds, but the other five were an average of 5 seconds faster at reacting to speech alarms, suggesting that a voice-alert system could improve safety on spacecraft.

Plants forget stress on purpose

FORGET-ME-NOTS like to forget.

Some plants have a long-term memory of things such as drought, priming them to tackle such future stresses quicker. But it seems that forgetting may be more beneficial – and the norm.

When Peter Crisp at the Australian National University in Canberra and his colleagues scoured previous studies for examples of plant memories, they found that it is unusual.

“Generally plants are good at forgetting,” says Crisp. His team argues that plants are making a trade-off. While being primed against previously experienced stress can be beneficial, it also comes with the cost of expressing genes when they aren't needed (*Science Advances*, doi.org/bcp2).

Double stars cleared cosmic fog

IT'S too big a job to do alone. Twin star systems may be responsible for shaping the early universe.

When early stars formed, their light couldn't be seen as their galaxies sat in opaque gas. This gas wasn't transformed into a transparent plasma until stars emitted bright ultraviolet photons that could escape the galaxies.

But there is a catch: not enough photons seemed to make it out. Models of early galaxies suggest only 1 per cent of photons left. Yet observations of the early cosmos show that 20 per cent are passing through intergalactic space.

Now Phillip Hopkins of California Institute of Technology and his team know why: the models only included solo massive stars, which produce most of the photons but are too short-lived to give them enough time to clear a way through the galaxy. But most stars circle a stellar sibling in a binary dance.

Once the team added binary stars into their models, the percentage of escaping photons jumped to 20 – perfectly matching predictions. “We were kind of shocked,” says Hopkins. “It changed everything.”

The key could be that a massive star with a companion can steal fuel from its neighbour, extending its life. This would buy enough time to clear the intergalactic medium (arxiv.org/abs/1601.07559).



J. MALZAPPELLANIZ / (A) NASA / (ESA) / STSC / SCIENCE PHOTO LIBRARY

A crab, a shrimp and a fish go into a burrow...

IT SOUNDS like a joke. A crab, a shrimp and a fish went into a burrow, and they left it together – doing the conga. In reality, it's part of a rare three-way symbiosis.

Predators abound on coral reefs, so some species of shrimp and fish team up for protection: the shrimp digs out a burrow and reinforces it with bits of shell and coral, and then takes in the fish as a lodger. The fish gets a refuge, the shrimp gets an extra pair of eyes to watch out for predators.

Now Alexandra Hiller of the Smithsonian Tropical Research

Institute in Apartado, Panama, and her colleagues have found that some homes have a third tenant – a porcelain crab (*Marine Biodiversity*, doi.org/bcnp). “It is very rare to find more than two participants in a symbiosis,” says Hiller.

They found six instances of porcelain crabs sharing burrows with pistol shrimp and gobies near a reef in Lembeh Strait, Indonesia. The animals typically exit the burrow together, in a chain – with the crab's claw and antennae touching the shrimp's

body and the shrimp's antennae nearly glued to the fish's tail.

If one spots a predator, it wouldn't take long to pass on the message. The movements of the shrimp and fish may also help the crab to feed, because they disturb the bottom sediment, which could allow the crab to filter organic detritus from the water. The symbiosis is unusual because the animals are evolutionarily distant, Hiller says: “Coming from such different groups that cooperate together is something that is very rare and fascinating.”

Work out to boost mood and memory

GET your shorts on and work on that mental muscle. Just 20 minutes of exercise can boost brain chemicals vital for memory and mood.

Researchers scanned the brains of 38 healthy volunteers before and after they cycled vigorously for 20 minutes. Exercise increased both glutamate and GABA – two vital neurotransmitters that help brain cells talk to each other (*Journal of Neuroscience*, DOI: 10.1523/jneurosci.3455-15.2016).

“The effects lasted for about 30 minutes after the end of the exercise session,” says Richard Maddock at the University of California, Davis. Levels of both chemicals were higher at the beginning of the study in volunteers who had worked out within the previous week. This suggests that regular exercise can lead to a sustained increase in the neurotransmitters.

Maddock says early results from a second study suggest that the boost in chemicals improves memory performance. His team plans to test whether these changes could also help people with depression, who have lower levels of both glutamate and GABA.



TARA MOORE/GETTY

B0 smells sweeter if you're 'one of us'

IT'S enough to make you wrinkle your nose in disgust. Being within sniffing distance of someone's bodily secretions may produce this response, which evolved to protect us from pathogens. But knowing they came from a member of our own group seems to make them more palatable.

A team led by Stephen Reicher at the University of St Andrews, UK, asked students how disgusted they were after smelling a heavily soiled T-shirt bearing the logo of another university. At the start of the trial, the researchers manipulated the way students viewed themselves,

emphasising either their affiliation to their university or their general status as students. The students were far less grossed out when they thought the T-shirt belonged to a fellow student rather than one at a rival university. It seems that knowing someone is “one of us” lowers our natural biological defences, perhaps enabling us to get closer to the rest of the group, suggests Reicher (*PNAS*, DOI: 10.1073/pnas.1517027113).

The fact that our loyalties can affect a core biological response shows how powerful and malleable group identities can be, says Reicher.

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We'll post updates on the show here in the magazine, at newscientistlive.com and on our Facebook and Twitter accounts. Sign up to our email newsletter or follow us on social media to get the latest announcements and find out when tickets go on sale. I hope to meet you in September!

Sumit Paul-Choudhury, editor

To find out more, go to
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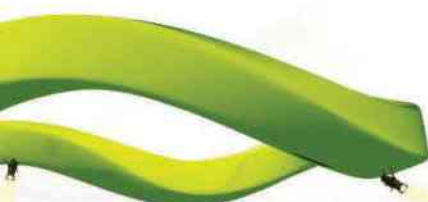
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ARTIST'S IMPRESSION

LONDON'S NOT-SO-LITTLE SECRET

The capital is a perfect place to hold a festival of scientific ideas

Think of London, and what comes to mind: Buckingham Palace, West End theatres, perhaps it's the bustling energy of the City? There's no doubt London is a global cultural, financial and tourist hub. Less well known is that it is also a science powerhouse.

"Scientific research is a global cooperation but London is a leading centre. It has 23 major universities and research centres," noted Stephen Hawking. As well as its long-standing strengths in basic research and engineering, the city has more recently built a vibrant

digital start-up scene, nurtured in part by its Tech City initiative.

Two years ago, London mayor Boris Johnson, launched a £4 million bid to recreate this success in the life sciences, along with London & Partners, which promotes the metropolis around the world. That initiative, called Med City, will help London universities, start-ups and big business to compete with other global biotech hubs.

This is just one of several huge life science initiatives in the city. Later this year, the Francis Crick Institute will open its doors. A £650 million

project, it will employ 1500 people, making it Europe's largest biomedical research centre.

There are other science initiatives being created at all points of the compass. A few miles to the south, the London Cancer Hub is being set up in the leafy suburb of Sutton. This aims to develop at least two new cancer drugs every five years.

UCL East is a research and learning development being built on the site of the 2012 Olympics, and Imperial West is a similar project on the city's west side. These are backed by two of the world's top-

ranked universities – University College London and Imperial College. Two more world-beating universities are a short ride away in Oxford and Cambridge, making "a golden triangle" for science.

All this adds up to a programme that Johnson described as London securing "the crown it first acquired in the 17th century as the scientific capital of the world". The fruits of these initiatives and many others, from all over the UK and the rest of the world, will be described and displayed at New Scientist Live.

Jeremy Webb, editor-at-large



Keeping an eye on civil liberties

Apple vs FBI: First salvo in the information war

In standing up to the FBI in the name of its customers, Apple is pitting company against state. It's a dangerous precedent, says **Hal Hodson**

THE iPhone that started it all was found in the rented car used by Syed Rizwan Farook and Tashfeen Malik, after both had been killed by police in December. Four hours earlier the pair had killed 14 people and wounded 22 more in a mass shooting in San Bernadino, California.

The FBI thinks the phone holds

valuable evidence but has been unable to bypass the phone's lock screen to access the information stored on it. Last week, the FBI publicly demanded that Apple help it break in. Apple said no.

In an open letter to customers posted on Apple's website, CEO Tim Cook argued that breaking into the phone would weaken the

security of every iPhone. Cook made it clear that in its civil disobedience Apple was making a stand against the US government to protect the rights of all its customers. It was a popular move. The letter has been shared hundreds of thousands of times across various social media sites.

Such a public stand-off is

unprecedented, highlighting the power that Apple – and tech giants like it – holds on account of its vast userbase. What the FBI wants is achievable from a technical point of view (see “What the US government wants”, below). But it is a political minefield. By choosing to carry out the confrontation in public, both the FBI and Apple are hoping to set a precedent in the court of public opinion in the ongoing battle over who has control over our private data, which is increasingly a key to our wider lives.

“Tim Cook's letter is a real declaration of war,” says Ian Brown of the Oxford Internet

“Tech giants are the new wave of colonialisation - they're creating their own empires”

Institute in the UK. “It's almost the first war of the Information Age between state and non-state actor – the most powerful state actor in the world.”

A confrontation of this sort has been bubbling up ever since Edward Snowden released documents that shed light on the US government's secret snooping on its citizens. That prompted several tech companies to make public statements opposing such surveillance activities.

In positioning themselves in opposition to states, tech giants have taken on certain state-like characteristics. “If you look at Google and Microsoft, they don't just have the power of states, they even organise themselves like states,” says Brown. “Microsoft has a foreign service that negotiates with foreign governments.” Facebook has its own internal counter-terrorism unit.

Paul Bernal at the University of East Anglia, UK, sees a parallel between Apple's fight with the FBI and Facebook's recent battle

with India's telecoms regulator. "There's a sense that the tech giants are the new wave of colonisation," he says. "In a way, they're creating their own empires."

Harry Halpin at the World Wide Web Consortium points out that these companies also co-opt certain functions of states. Governments issue their citizens with passports and driver's licences to verify identity. Online we use IDs provided by Google, Facebook and Apple. Digital payment systems tied to these IDs, such as Google Wallet and Apple Pay, give these companies even greater influence. This allows the world's tech giants to govern access to our money, our digital possessions and our data.

"It's not that nation states are becoming less powerful, it's that some of their roles are being absorbed by post-national frameworks," says Halpin.

The state-like power of large tech companies is also evident in their ability to minimise their tax bills around the world, placing themselves in direct opposition

to governments. In 2014, for example, Google moved \$14 billion out of the EU to avoid tax.

Of course, there are other multinational corporations with large amounts of power. Because of its size, oil company Exxon has a lot of influence in the countries in which it operates, for example. Nor is it a new phenomenon. In the 18th century the East India Company effectively ran India and the Barings banking dynasty has been described as one of the six great powers of Europe.

Brand loyalty

However, tech giants have something new: millions of loyal customers, many of whom choose to side with companies over their government. This is especially true in the dispute about privacy and encryption. In this light, Apple is protecting its citizens.

"It always takes one to stand up," says Nikhil Pahwa, co-founder of the Internet Freedom Foundation. "Others follow."

But is this a good thing? Pahwa and colleagues spearheaded the

Save the Internet campaign that helped defeat Facebook's Free Basics programme in India – a campaign that largely attacked Facebook's state-like pretensions. However, Pahwa supports Apple's behaviour. Apple makes its money selling hardware, he says. Facebook makes money by selling its users' data. For Pahwa, Apple's business model makes it a benign power.

Brown disagrees. Apple's stand contains a major irony, he says. Apple's protection of its user's privacy may be a good thing – and privacy advocates applaud the firm's stand – but its accumulation of power is dangerous.

Tech companies shouldn't be above the rule of law by dint of the size of their customer base, says Brown. For all the FBI's faults, the agency emerges out of a democratic system that – at least in principle – is designed by and for its citizens. Apple emerges out of the free market, and is beholden only to its shareholders. "How do you apply concepts that constrained states in the past – human rights, war conventions, trade agreements?" asks Brown.

Of course, it is important to remember that Apple's public stand-off could just be a trillion dollar game of smoke and mirrors. Apple reportedly asked the FBI to keep its request sealed, hidden

"This is quite a moment in history - will citizens support companies standing up for them?"

from public eye. Apple could be knuckling under behind scenes, bound by secret court orders, handing over the private keys. We have no way of knowing.

"This is quite a moment in history," says Pahwa. "We'll see whether citizens support companies standing up for them or not." In the US, public opinion is easily swayed by concerns for national security. In the end, everything may ride on what's on that phone – if we ever find out. ■

ONE PER CENT



Facing up to a paradox

Watch those worry lines. Face-reading software has scrutinised videos of 200 CEOs of major companies, including FedEx and Citigroup, and found a link between negative emotions and positive financial performance. Firms with CEOs that wore fearful expressions saw a 0.4 per cent rise in stock prices within the following week, while those who showed disgust saw a 9.3 per cent increase in profits in the following quarter.

\$4.5 million

It's the biggest speaking fee ever. But there's a catch: to earn the IBM Watson AI X Prize, you must design the artificial intelligence that gives the best 18-minute talk at the TED2020 conference.

Picked out of hats

Prospective Google employees are set this puzzle. A hundred people stand in a line wearing red or blue hats. Each only sees the heads of those in front. How can they devise a strategy to maximise the chance of guessing what colour hat they themselves are wearing? A neural network based on one built by Google's DeepMind team has found a solution, one that could help groups of robots work together to solve puzzles by sharing information.

IMAGE SOURCE / ALAMY STOCK PHOTO

WHAT THE US GOVERNMENT WANTS

The FBI wants to access data stored on an iPhone used by one of the San Bernadino shooters. The phone is the property of the shooter's employer – the Inland Regional Center – which has given the FBI permission to access it. But the data is encrypted and only accessible if the phone is unlocked using a pin number that the FBI doesn't have.

The pin cannot be cracked by repeatedly trying various number combinations as the iPhone has a security feature that introduces a delay of increasing length after each incorrect attempt. What's more, the pin cannot be bypassed – by opening up the phone and copying the data, say – because the phone's encryption is tied to a unique hardware key on the phone itself. In short, the FBI can only break in with Apple's help.

The agency has asked Apple to

build a special version of the iPhone operating system, which can be force-installed on the locked phone without wiping the data. The update would remove the feature that introduces delays after incorrect pin entries so they can make huge numbers of guesses with a powerful computer, and eventually unlock the phone. Yet security researchers have pointed out that even then it could take a long time. If the phone is locked with a four-digit pin this will take a few minutes. But if it is locked with a six-character password including letters and numbers it could take more than 300 years.

Still, Apple is objecting on principle. It argues that unlocking one phone amounts to unlocking them all, equivalent to creating a master key capable of opening hundreds of millions of locks.

AI reads doctors' notes to find links in cancer cases

BLOOD count. Biopsy. Drug cocktails. Snippets like these tell the story of a person's experience of cancer. Gather up their stories and you could learn about the disease itself.

A team at Memorial Sloan Kettering Cancer Center in New York has started training an artificial intelligence to read and understand those stories. The software combs through 100 million sentences taken from clinical notes about people with cancer.

"We're looking into the exhaust of all that data to try to find something interesting," says Gunnar Rätsch, who works on the project. The idea is to build models that capture how the disease progresses then use them to make predictions.

The algorithm sorts each sentence into one of 10,000 clusters, each representing an observation found in numerous records. For example, a note recommending a course of treatment, or picking up on a noteworthy symptom. Connections between clusters were then mapped, showing the relationships between different comments or treatment regimes.

Now the clusters are being compared with individual records, looking for associations between written notes, genetic profiles and blood results. "The human mind is limited, hence you need to use statistics and computer science," says Rätsch. Aviva Rutkin ■



Laid low by ransomware

Pay up or your medical records will be toast

EVEN data can be held hostage. Last week a California hospital paid out \$17,000 to hackers who had taken over its computers. It's the most high-profile case yet of cyber extortion using ransomware.

Malicious software can infect computers when someone clicks on a link to a booby-trapped website, or opens an attachment in a phishing email. Ransomware is malware that typically encrypts all the files stored on a system and then demands payment to unlock them.

The attack on Hollywood Presbyterian Medical Center in Los Angeles effectively knocked it offline. As a result, patients had to be diverted to other hospitals, medical records were kept using pen and paper, and staff resorted to communicating by fax. Although they settled for far less, the hackers had reportedly demanded 9000 bitcoins – around \$3.6 million.

"Ransomware has really

exploded in the last couple of years," says Steve Santorelli, a former UK police detective now at threat intelligence firm Team Cymru, based in Florida. One ransomware package, CryptoLocker 3.0, is thought to have earned attackers \$325 million in 2015 alone.

"These guys are sophisticated," says Jake Williams, the founder of cybersecurity firm Rendition InfoSec. Some even have help desks lurking on the dark web, and will decrypt one of their victim's files to prove that they have the key.

Williams says his company has worked with several healthcare providers who have been attacked. When clients don't have their files backed up and the ransom is small – hundreds of dollars, say – the firm advises paying up. "We tell them: before the attackers realise they've got a much bigger fish on the hook, go ahead and pay immediately," he says. "In every

case we've worked with, if you pay the ransom, within a couple of hours you get the key and are able to decrypt your files."

Ross Anderson, a security researcher at the University of Cambridge, says bitcoin has helped cybercriminals access payments without being caught. "In the old days, collecting ransom was really hard," he says.

"Cybercriminals even have help desks on the dark web, and can decrypt a file to prove they have the key"

"The police would just put a radio tracker in the carpet bag full of £20 notes, and they would always get the guy. Now that it's possible to collect ransoms by bitcoin, lots of people are doing it."

This is not to say the criminals can't be tracked down. "Good cybercrime investigation is about turning over thousands of little rocks looking for the mistakes that the criminals have made," says Santorelli. "And they always make mistakes." Williams says in some cases his firm has been able to trace attackers to locations in eastern Europe.

Protecting against ransomware is easy: back up your files frequently and make sure your network is segmented – divided up in such a way that an attack on one machine can't spread. It would appear that Hollywood Presbyterian was not so well prepared, and it had to shut down its network after the attack.

For hospitals in particular, the goal of some attacks may be not so much to withhold files as to grab what they contain. "We've seen malware in healthcare environments that's been able to steal patients' information," says Williams. School districts and police departments have also been targeted. "Until healthcare in particular and some of our other critical infrastructure start taking this seriously, you're going to see these attacks for sure," he says. Sam Wong ■

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Cry me a snowflake

ARE these bubbles, bacteria or perhaps space rocks? No - they're human tears as you've never seen them before.

Each disc is a tear droplet that has been pipetted onto a glass slide, allowed to evaporate and photographed using dark field microscopy. The delicate white structures are the crystallised salts left behind from the briny fluid. As well as salts, tears contain antibodies and other proteins that combat infections and help protect the eye.

Photographer Maurice Mikkers got the idea while imaging crystals of pharmaceutical drugs. He happened to bump into a table hard enough to trigger tears of pain, which became the subject of his next pictures. "I was amazed by what I saw," he says. "People could not believe how beautiful it was." Now he is seeking people to weep on demand for his growing collection.

Mikkers advises his volunteers to have their own crying triggers prepared - sad movie scenes on YouTube or onions, for example. Tears of happiness are also welcomed. "It's very personal."

One crystallised tear looks different to the next, with no obvious hallmarks that could identify the person who produced it. "Every tear is as unique as a snowflake," he says. Clare Wilson

To find out more about why we weep see "A Good Cry" on page 42.

Photographer

Maurice Mikkers

A clean break?

A UK exit from the European Union would risk environmental gains and its ability to tackle global challenges, warns **Fiona Reynolds**

THE fight over UK membership of the European Union has reached a critical stage. Prime Minister David Cameron has renegotiated the terms of the UK's membership, but will the country vote to stay in the EU in June's referendum?

The backdrop is a worrying one: a debate dominated by economics and immigration, with other key issues barely getting a look in.

Among those issues is the fate of environmental protections to ensure clean air and water, preserve treasured habitats and address global warming should the UK leave the EU. Most of these protections were agreed at the European level. Brexit – a British exit from the EU – would throw them into doubt.

After 35 years of campaigning to protect the UK's landscape, nature and cultural heritage, I'm clear where I stand. If the country



hadn't been in the EU for the past 40-odd years it wouldn't have the cleaner beaches and rivers, safeguarded landscapes and less polluted air enjoyed today. These could be undermined if the country votes to leave.

Such protections weren't imposed by an aggressive Europe, as critics suggest, but negotiated by the UK, in collaboration with other members, for the good of our collective future.

And with the looming pressures of climate change and a growing world population with multiple needs, Europe requires more scientific, policy and political collaboration, not less.

The world is getting more vulnerable as it becomes more connected. We're using resources as if we had three planets, not one; and we face huge challenges driven by political and economic uncertainties. As a result, many

That sinking feeling

Is it game over for Earth's best hidey hole for a nuclear deterrent, wonders **David Hambling**

AS THE UK debates spending billions to update its nuclear missile submarines, critics claim that underwater drones will soon blow their cover, making the project pointless. Are they right?

In recent years, marine research has been transformed by a new type of uncrewed submarine known as a glider. Typically

looking like torpedoes with wings, they don't have a propeller, instead altering buoyancy in order to glide. This slow, frugal propulsion allows them to go for months on a single battery charge.

Glider have been used for extended tracking of oil spills, pollution and fish. And they are near-silent, making them ideal

for anti-submarine missions.

This would explain the proliferation of US navy glider projects, including the Persistent Littoral Undersea Surveillance system, the Littoral Battlespace Sensing-Glider and stealth-bomber shaped Liberdade Series gliders.

The Chinese are also interested. Their first glider was launched in 2011 and there are now dozens of projects, with a focus on speed, endurance and getting multiple

"Small, cheap underwater drones could be deployed to form arrays covering a wide area"

gliders to work together. Chinese state media reports its Haiyan glider has an anti-submarine role.

Anti-submarine drones will benefit from rapid gains in computing power, since the search is all about signal processing. Whichever detection method the drone uses, the challenge is telling signal from noise. Drones have the advantage: they now pack more processing power than submarines of a few decades ago, thanks to Moore's law. New sensor types, including lasers that can pierce seawater, are making them more capable.

In addition, much US research focuses on multiple sensors

parts of the world, Europe included, face flood, drought or pressures on scarce resources.

If UK citizens care about the planet and future generations, they must cooperate – the country can't find solutions on its own.

Being in the EU is not, of course, of itself a solution. It will only be a platform for environmental and scientific collaboration if people keep pushing it in that direction.

And of course not everything the EU does is positive: like many environmentalists, I spent years campaigning for changes to its agricultural and fisheries policies to stop them damaging wildlife, landscapes and cultural heritage. But the UK negotiated beneficial changes to those policies. Despite its shortcomings, being a member of the EU has worked for the environment.

Talk of Brexit is usually sold as a way of regaining national identity. But this is an isolationist view. Britain has a long history of working with others and much success in doing so.

At a time when we need to think about our future as citizens of a shared planet, Brexit would be an inconceivably risky step to take. ■

Fiona Reynolds is chair of think tank Green Alliance, and master of Emmanuel College, Cambridge

networked in sparse arrays. Small, cheap drones could be deployed to form arrays covering a wide area. That's great for whales, as low-power sensors are less damaging than high-powered sonar, but bad for submarines trying to hide.

Aerial drones have spread rapidly in military and civilian life. When the successor to the UK's Trident nuclear submarine fleet is launched in 15 years or so, it would be surprising if the seas were not full of robots waiting to follow its every move. ■

David Hambling is a science writer. His latest book is *Swarm Troopers: How small drones will conquer the world*

ONE MINUTE INTERVIEW

A different kind of thriller

This is a story about focused ultrasound and it's the most important book I've ever written, says **John Grisham**



PROFILE

John Grisham is an award-winning author and lawyer, best known for his legal thrillers. He is on the board of directors at the Focused Ultrasound Foundation in Charlottesville, Virginia. *The Tumor* can be downloaded for free at fusfoundation.org

Can you tell me about *The Tumor* – your first non-legal thriller?

A man called Paul is diagnosed with a terrible brain tumour, a grade four glioblastoma. The first version of the story is what happens now: Paul has surgery, chemotherapy and radiation. He dies within nine months. It's devastating. The second version is what could happen by 2025. Paul is treated with focused ultrasound therapy. It isn't a cure, but makes his cancer chronic and treatable. He lives 10 years or more, sees his kids grow up.

So what is focused ultrasound therapy?

Focused ultrasound can destroy tumours using beams of ultrasound energy. It can also cook the microscopic bits of a tumour that normal surgery can't reach. It is non-invasive, painless and relatively inexpensive.

What conditions can it be used to treat?

In the US it's approved to treat uterine fibroids, pain from bone metastases and prostate cancer. In Europe it's approved for many other conditions

including liver cancer, kidney cancer and Parkinson's. Globally, there are 58 disorders for which it is in research and development.

How did you, as one of the world's most prominent storytellers, get interested in this?

My friend Neal Kassell, a neurosurgeon and chairman of the Focused Ultrasound Foundation, began talking about focused ultrasound non-stop. He asked me to join the board of the foundation to help raise awareness. As a semi-celebrity I get asked to join a lot of boards so I was a little hesitant at first. But then I realised what this technology could do, and how many hundreds of thousands of people could benefit. It has such potential for saving and improving so many lives.

What do you hope to achieve with your book?

The book is free – we want to expose people to the potential of this technology. We don't want to give false hope, but we want to create excitement and awareness and also get people to consider giving money for research.

Did you go and see any focused ultrasound therapies before writing *The Tumor*?

Yes, I watched a young lady being treated for uterine fibroids. She was wide-awake the whole time; her husband was holding her hand. A close friend also had the same painful condition. After focused ultrasound therapy her transformation was remarkable. Traditionally, both women would have had a hysterectomy, a major surgery that is expensive, takes six weeks to recover from and destroys their fertility. Instead, these women went home immediately with their fertility intact.

How have people reacted to the book?

When readers sound off anonymously online they can say some pretty nasty things. But the reviews have been good for this one. I've always aspired to entertain people with high-quality fiction, but *The Tumor* is different – it has the power to promote a technology that may save millions of lives. It's the most important book I've ever written.

Interview by Helen Thomson

Curious genitalia are signposts of evolution

Elaborate and peculiar sex organs give us eye-opening insights about the world, says **Brian Langerhans**

What made you want to study genitalia?
I just wanted to understand how there is so much biological diversity in the world. And to do that, it made sense to me to study the evolution of one of the most rapidly evolving things known in the entire animal kingdom – male genitalia.

How do you explain what you do when you're at parties?
I usually pitch my research regarding genital diversity as trying to understand how the world works.

If you want to understand how all this life has evolved, then you need to know what causes the rapid evolution of traits that are the most elaborate and peculiar. You also want to be able to answer questions about what traits influence the origin of new species, and how human activities might drive rapid evolutionary change. Male genitals are a good place to look to address those questions.

You study the genitalia of both sexes. Why have penises hogged the limelight in biology?
Science is finally getting around to studying female genitals in earnest, and understanding how important these structures are – and we are seeing a lot of really interesting and complex variation. But historically it was received wisdom that female genitals just didn't vary that much, so why bother? The male structures are very obvious because they often have hard, rigid attributes that are much easier to measure. Female genitals are typically made of soft tissue that can conform to different sizes and shapes during different activities, and often have no obvious external features that can be measured.

So, historically, scientists went for the low-hanging fruit, so to speak.

What is the most elaborate and peculiar set of genitalia you've encountered?
It's hard to pick just one. Reproductive organs that have really elaborate spikes, hooks or some sort of weird pointed appendage are more common than you might think: there are thousands of outrageous sets of genitals in the world. You can see some crazy beetles that have spikes all over their sexual organs. Bedbugs have sword-like appendages that they use to pierce the abdomens of females in order to inseminate them. Some primates have enormous testes. Mosquitofish, which I study, have these harmful-looking spikes on the male sex organ, or gonopodium. And there are even species, such as squirrels, that have sexual organs to insert plugs into the female to prevent future mating.

Many male genitals look more like medieval torture devices than organs that transfer sperm from A to B. It makes you wonder why any female would ever mate with them.

And the strangest female genitalia?
A peculiar one I found is in the live-bearing fish *Gambusia vittata*, which looks dramatically different from its close relatives. The female has evolved a flap of tissue that conceals the entire genital region. Copulation in these fish is extremely rapid and athletic, with males performing a complicated torque-thrust manoeuvre in just 20 to 50 milliseconds, including dealing with this flap. The genitalia of both sexes in this species is so peculiar that the species was originally given in its own genus, *Flexipenis*.

PROFILE
Brian Langerhans is an assistant professor of ecology and evolutionary biology at North Carolina State University in Raleigh. He explores the evolution of biological diversity



How did human genitals end up with such relatively boring structures?

I don't know if I'd say they were boring. Clearly, human genitals serve a function and are performing that function quite well. If we put the human penis in the context of the entire animal kingdom, say, we see that you don't always need spikes, hooks or plugs to get the job done. Evolution always comes up with multiple solutions to similar problems.

Photographed for New Scientist by Travis Dove



What drives the diversity of male genitals?

There doesn't seem to be a lot of natural selection at play. We're reaching a consensus that male genitalia are so diverse because of sexual selection, or selection that acts on traits that bring about reproductive success. These very different types of genitalia have evolved to make sure that these species can keep successfully reproducing in whatever environment they are in.

What's the difference between natural selection and sexual selection?

Darwin originally defined the two terms as a dichotomy, but they are essentially the two major components of evolutionary fitness. A species has to be able to survive day to day – and it has to be able to reproduce. Natural selection acts on the surviving, whereas sexual selection acts on the reproducing. It's the latter that seems to be driving the rather dramatic diversity we see in penises and testes.

You study how human activities are affecting mosquitofish genitalia. What's happening?

We look at mosquitofish in tidal creeks across different islands in the Bahamas. Over the past 50 years, there have been a lot of roads built to connect different settlements across the islands, and they've dramatically changed the landscape. I'm sure the last thing the Army Corps of Engineers was thinking about as it built these roads was, "I wonder if blocking off this creek might change the reproductive organs of the fish that live here". But that's what happened.

These creeks used to connect to the ocean and were huge nurseries for all kinds of other fish. Once they were blocked off, those populations went away. Predation of the mosquitofish plummeted and the mosquitofish gonopodia got much bigger. And not just the gonopodia – we also saw changes to the female genitalia in these species. With less predation, the genital openings of females are larger and more oval-shaped. And all of these changes to the genitalia have evolved rapidly, in just four or five decades.

"So many sets of male genitals look like medieval torture devices"

What can we learn from these effects?

Our activities aren't just changing mosquitofish genitals. Or even just animal genitals. They are also making changes to different species' body shape, colour, habits and other things – and really fast. We need to learn about how human activity affects the ecology of different biological systems, so we can prevent damage that, if we aren't careful, we can't undo.

Is bigger better for the animals you study?

Female mosquitofish prefer to associate and mate with males that have a large gonopodium. But those males experience increased drag thanks to that larger organ hanging off their body, so what they gain in mating, they lose in manoeuvrability and speed. And that's a big problem, because if you're swinging around this large gonopodium, you may find that you're not only catching the eye of the females, but also the eye of predators. Fish with a bigger gonopodium are more likely to get eaten. ■

Interview by Kayt Sukeel

Thinking 2.0

To grapple with the modern world's problems, we need new ways to reason from cause to effect, says **Michael Brooks**

IT IS not obvious what connects a falling apple and the rising sun. It took a genius to realise these two effects are the product of a single hidden cause, one that also explains the stars' positions and the fact that our feet are firmly planted on the ground – the invisible pull of gravity.

That genius was Isaac Newton, a man gifted with “the power of holding continuously in his mind a purely mental problem until he had seen straight through it”, in the words of economist John Maynard Keynes. We could use a few of his stamps now more than ever. While Newton's successors stutter as they try to find further unifying laws of the cosmos, the world at large grapples with problems on unprecedented scales – economic instability, poverty and disease, climate change.

Finding solutions means doing what Newton did with gravity: asking the right questions, teasing out causes and effects, and so building an intellectual framework to explain the puzzle. But how do we do that with the sheer quantity of data sloshing around in today's world? It's this problem that has led some to think we need to think seriously about the way we think. Only by rebooting our powers of logic and going beyond what nature has hardwired into our brain can we hope to grapple with problems that are far bigger than any of us. It's time to install Thinking 2.0.

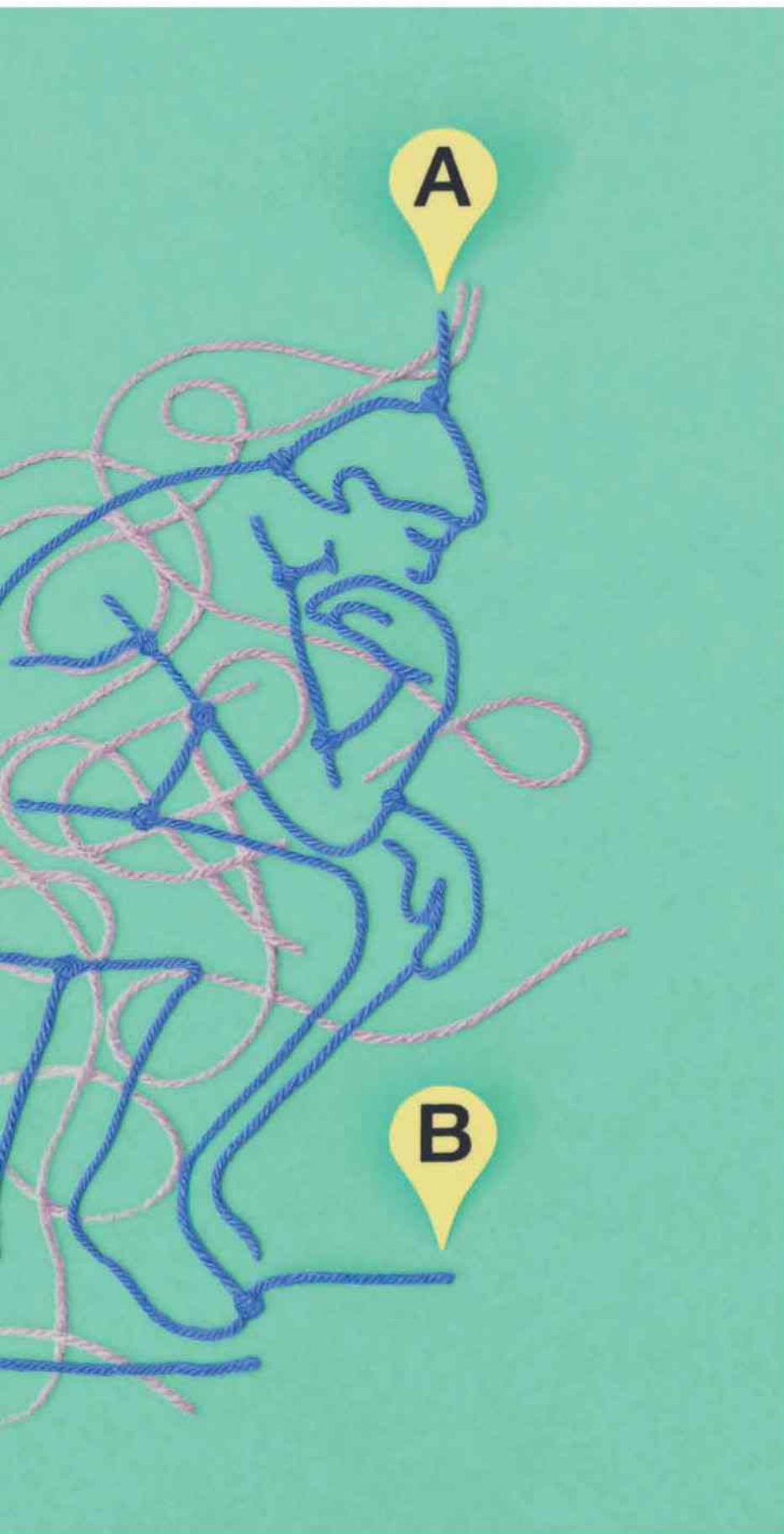
For most of us, Thinking 1.0 is taxing enough. We humans love to sideline logic in favour of the easy answer. We might make

life decisions based on newspaper horoscopes, champion medicines that don't really make us better or follow the same diet that didn't work last year. Collectively, we convince ourselves we can put off making hard decisions about tackling climate change until tomorrow, and stake our futures on economic models that bear no resemblance to the real world.

Scientists, those supposed guardians of cold logic and rational thinking, are by no means immune. Here the most acute problem lies in statistical analysis – used correctly, the best way to extract meaning from a large amount of data, but all too often prone to oversimplification or flawed claims.

“Statistics is presented as a way of being careful about the world and not making claims that aren't supported by the data, but it ends up being a licence for people to believe things that they would never otherwise have believed,” says Andrew Gelman, a statistician at Columbia University in New York. “It's an excuse for people to turn their brain off.”

He cites findings from recent eye-catching studies with statistical flaws that good-looking parents are more likely to produce female children, or that women tend to wear red clothing when ovulating. Back in 2005, researcher John Ioannidis, now at Stanford University in California, claimed that sloppy statistics could mean that more than half of scientific papers reach flawed conclusions. Neuroscience and psychology are areas that have come under particular scrutiny



recently for possibly flawed assignments of cause and effect.

Now, as never before, screeds of information are logged digitally every day and stored in perpetuity, from government records to ocean surface temperatures. Couple that with the relentless rise of cheaply accessible computing power and it's clear that the potential to find answers is greater than ever before – but the possibility of finding the wrong ones rises.

The challenge starts in asking the right questions, says social scientist Gary King of Harvard University. “Often the question isn’t well posed, or there isn’t a direct answer but there is another question that’s of interest.”

In the world around us, cause and effect are often unambiguously defined, and the right questions and answers are similarly clear. I kick a football, the football moves. The question “What made the football move?” is as obvious as the answer “I did”. But then take a cock’s crow before dawn. An incautious statistical analysis might show that the one precedes the other sufficiently often that the crowing causes the sun to rise. We only know that is nonsense because independently acquired knowledge tells us we live on a rotating planet – an entirely different assignment of cause to effect.

Big and messy

Often we don’t have that independent knowledge. Say a clinical trial involving a large group of people shows that a new drug is effective at treating an illness. Break things down, though, and it turns out that the recovery rate is lower for men who got the drug compared with those who didn’t – and it is also lower for women. “If you try to interpret this in a causal fashion, it seems paradoxical,” says Robert Spekkens, a physicist at the Perimeter Institute in Waterloo, Canada. This is an example of what’s known as Simpson’s paradox, and the reason is that the drug does not cause better recovery – it’s actually your sex that does (see diagram, page 36).

In a structured environment such as a clinical trial, such potential pitfalls can generally be circumnavigated through means such as control groups, in which some people take no drug or a placebo. But often controls aren’t possible, and the waters may be muddied by irrelevant, confusing or missing data. The UK’s groundbreaking post-war ➤

cohort studies, for example, followed a segment of the population throughout their lives to assess their health, wealth and happiness. But how do we tease out cause and effect from what will always be incomplete information, and so draw conclusions that help others improve their lives? “Big data are messy data,” says Gelman. Such data might show that quantities A and B shrink or grow together – but does that mean A is causing B? Or that both A and B have a common cause in C – or in D or E, about which we have no data?

Even professional problem-solvers fall down in such a situation. Richard Scheines of Carnegie Mellon University in Pittsburgh, Pennsylvania, recalls a researcher who came to him convinced his data showed that religious practices reduced stress and helped overcome depression. A more detailed breakdown, however, showed that stress was causing depression, and depression was causing people to turn to religion – and it was not clear that anyone was getting better anyway. “He was very disappointed,” says Scheines.

This, then, is the rub as we attempt to bring our homespun logic to bear on big problems. “People know that correlation does not equal causation, but they don’t grasp the depth of it,” says Judea Pearl, a computer scientist and philosopher at the University of California, Los Angeles. “You simply cannot grasp causal relationships with statistical language.”

Pearl has spent the past few decades pioneering more reliable tools. These are founded on a mathematical language that

for the first time enables causal relationships such as “the rooster crow does not cause the sun to rise” to be coded directly into a computer program. Algorithms built using this language enable researchers to reliably find the cause-and-effect relationships between the variables in a problem. Rather than combing a data set for things you think might be cause and effect, the algorithms instead create a hypothetical set of relationships and see if they fit with the data in every instance. In a similar way, a physicist would construct a model of a real-world

“We know that correlation does not equal causation, but we don’t grasp the depth of it”

situation and see if its predictions match with reality in all cases. Depending on the number of variables, building such a “causal structural model” can be a mammoth task – but it provides an independent logical template into which you can see if your data fits. “It gives you mathematical guarantees,” says Pearl.

This is seminal work, says Scheines, who is also a co-founder of the University of Pittsburgh’s Center for Causal Discovery, created in 2014 to exploit the new insights. “Pearl has been monumentally important to the revolution in causation,” he says. Most science, he points out, involves coming up

with a model of causes and effects, testing it, and modifying it when it fails – a wearying process. “We can now look to a computer to search billions and trillions of different models at the same time,” he says.

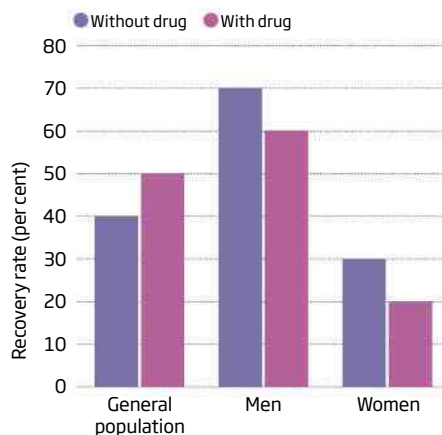
Slowly, the new techniques are gaining adherents. One early success came in 2012, when biologists and statisticians at the Swiss Federal Institute of Technology (ETH) in Zurich used causal discovery algorithms to pin down the genes responsible for determining the flowering time of plants. “They got it down to nine candidates from 25,000 genes,” says Scheines. Others are applying the methods to understanding causal relationships in cell signalling, and between genetic mutations and tumour development, as well as to tease out differences in the workings of autistic and neurotypical children’s brains. “This work is starting to penetrate the mainstream,” says Scheines – just as ambitious programmes such as the UK’s 100,000 Genomes Project are beginning to crunch gigantic swathes of data to find correlations, and perhaps causations, between people’s genes, diet, lifestyles and health, and the onset of cancer.

Alexander Bochman of the Holon Institute of Technology in Israel also thinks the new logical tools could be a game changer. “It is truly revolutionary,” he says. “It has shown that causal reasoning works and provides clear, reasonable and systematic answers to important questions.”

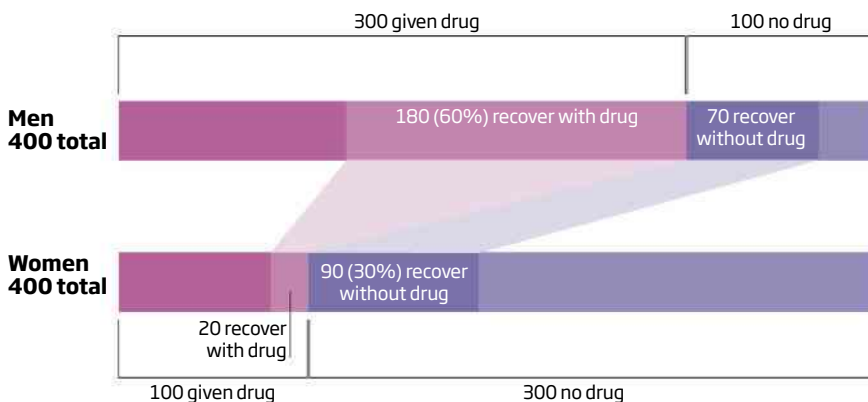
Together with Vladimir Lifschitz of the University of Texas at Austin, Bochman is

Masked cause

Teasing out the true cause of an observed effect isn’t always straightforward. In this study, an equal number of men and women with a particular condition were enrolled, but other factors skewed the result



The drug appears to improve recovery rates for everyone – even though it reduces recovery rates for both men and women. How?



Because far more men than women were given the drug in this particular study, the men’s higher overall recovery rate masked the drug’s negative effect. So for this condition, biological sex is a much higher predictor of recovery than taking the drug

boring down to the next level. They have been working to reformulate Pearl's mathematical notations into the more basic language that formal logicians use, enabling them to explore ideas of causality within logical frameworks that contain assumptions – and understand what happens when those assumptions are found wanting. “Assumptions are just beliefs, so they should be abandoned when we learn new facts that contradict them,” Bochman says. If we find the grass is wet, we might assume it has just rained, for example – until we learn that a new sprinkler system has just been introduced.

The “nonmonotonic reasoning” logic scheme that he and Lifschitz have devised allows a user to keep track of their assumptions, and update a chain of reasoning if those assumptions change. This provides a surer way to work with incomplete or changing information – a boon in interpreting “the vast range of vexed questions about causation and its role in science and beyond”, says Bochman.

Spekkens is approaching that same problem from a different angle. He is a quantum physicist – and there is no field of human enquiry in which questions of cause and effect are more vexed. Quantum theory describes with perfect accuracy phenomena that occur on atomic and subatomic scales, but only at the price of particles existing in two places at once, for example, or seeming to influence each others' properties without any physical connection.

Physicists explore this last phenomenon of “entanglement” using an experimental set-up known as a Bell test, which aims to exclude the possibility of standard, “classical” cause-and-effect influences being responsible for what is observed. Bell tests generally show that the experimental apparatus obeys our familiar classical causal rules, while the measured particles seem to be obeying a different, unfamiliar set. There are two responses to that: say “it’s weird” and carry on – or try to work out what the rules of quantum causality are, and whether they might give us a deeper insight into logic in the wider world.

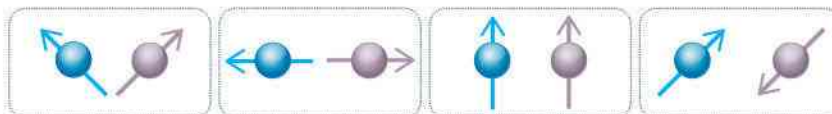
What Spekkens and his colleagues have teased out so far is that the way causality works in the quantum world allows a cause-effect relationship to be distinguished from a common-cause relationship – something nigh-on impossible in the classical world without using a control group (see diagram, above right). In other words, it allows us to sidestep those Simpson's paradox-type situations (*Nature Physics*, vol 11, p 414).

That could have direct consequences in

Quantum logic

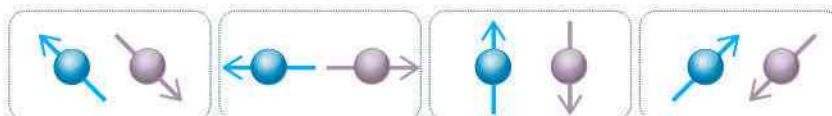
Quantum physics allows you to distinguish between cause and effect (one thing influencing another) and common cause (two things responding to the same effect)

You measure the polarisation of two particles, reset the detector, and do the same again. Classically, you expect a random correlation between the two polarisation orientations

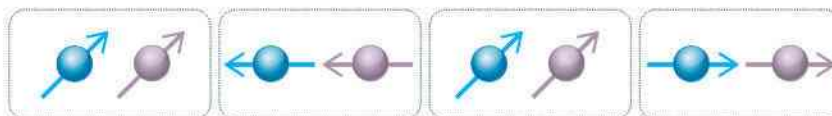


In the quantum world, you often measure a second polarisation that is opposite to the first.

Prior entanglement of the particles is the **COMMON CAUSE**



If your second measurement always aligns with the first, entanglement doesn't explain it. It is more likely that the first measurement is influencing the second: **CAUSE AND EFFECT**



fundamental physics. Entanglement seems to be based on a causal relationship that lies outside our conventional conception of physical space and time, phenomena dealt with by Einstein's general relativity. Find out more, and we might find a common cause that could unify relativity and quantum theory, two stubbornly incompatible theories. But Spekkens thinks it could also feed back into

“Entanglement seems to be based on a causal relationship outside physical space and time”

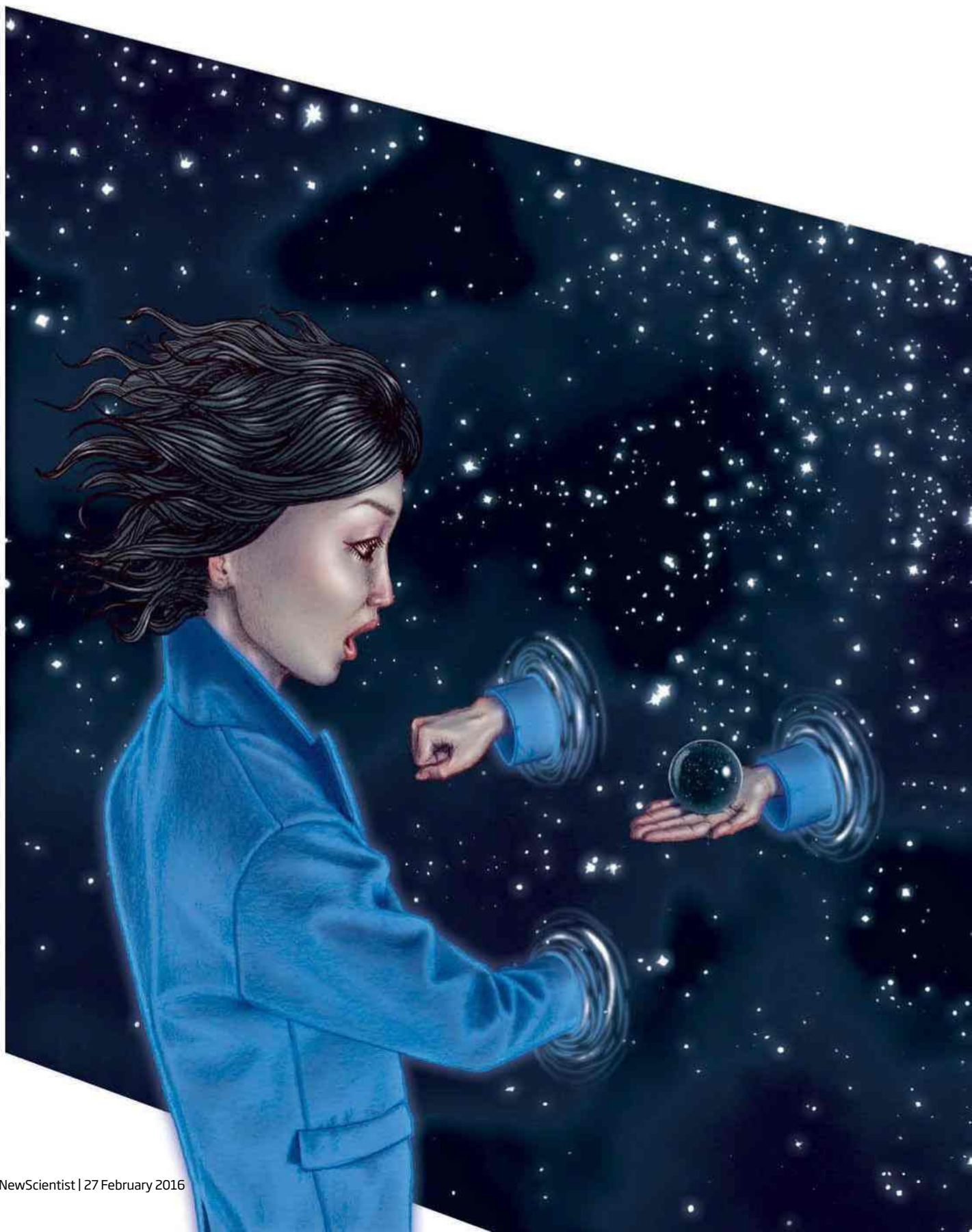
more rigorous logical analysis in the real world. There are undoubtedly more classical causal algorithms waiting to be discovered, he says, and perhaps the quantum analyses could allow us to discover ways to distinguish cause and effect from common cause in the classical world, too. That could potentially be of great interest, say, for clinical trials in which randomised controlled experiments can't be carried out for cost, technological or ethical reasons. In precise evaluations of the comparative effectiveness of end-stage cancer treatments, for example, it would be unethical to deny a control group any treatment at all. “If one could deliver on this promise, it would

be an interesting example of the field of quantum foundations having applications in other fields,” says Spekkens.

Spekkens is keen to point out that such tools complement, rather than compete with, conventional tools from classical logic. Pearl for one welcomes any synergy between quantum and classical thinking, and any approach that can increase the rigour and effectiveness of our approach to crunching data to solve the messiest of human problems. Rather than relying on presumptions of cause and effect made by often politically compromised economists, for example, he thinks we might use new thinking tools to crunch through all conceivable combinations of economic variables to work out which should be tweaked and under what circumstances, say to bring about more equality while not strangling economic growth. “There's a lot of research in this direction and it looks promising,” says Pearl. “We haven't yet discovered the cause of poverty, but we're moving in the right direction.”

If we can go beyond Thinking 1.0 to frame better questions and process data more reliably, we might all reasonably become geniuses – a cause that could mean a better future for all of us. “Maybe we will begin to think in more complex and subtle ways,” says Gelman. “That would be great.” ■

Michael Brooks is a consultant for *New Scientist*



Pick a universe

Any universe? What's to do when our best theories of reality can't be tested, ask Jim Baggott and Daniel Cossins

IN 1894, Max Planck was warming to a new challenge. A consortium of electric companies had commissioned Planck, then a physics professor in Berlin, to make a light-bulb filament generate maximum light for the least amount of energy. But there was a problem. The physics he knew predicted that a heated object should absorb and emit electromagnetic radiation at all frequencies, meaning it should generate infinite amounts of energy. Experimental data, not to mention common sense, suggested otherwise.

A few years later, Planck came up with a solution: if energy is absorbed or emitted in discrete packets, then the energy radiated by a heated object would be finite. The theory seemed absurd at the time, but once physicists started looking, these “quanta” popped up all over the place. Quantum mechanics now ranks as our most successful description of reality. The mind-bending phenomena it predicts – from photons and electrons existing simultaneously as wave and particle to distant objects acting as one – have come through multiple tests with flying colours.

The quantum world is bewildering, but the story of how it was revealed is a reassuring reminder of how science is supposed to work. We make observations, develop theories to explain them and test those theories. It's the testing that makes science science. It might seem odd, then, that some researchers are arguing that this approach is outdated for fundamental physics. Experimental proof is extremely hard, if not impossible, to come by. With that in mind, they say, we need a different way to develop trust in theories.

This proposal has been met with dark warnings from some quarters. Now the argument has escalated into what George Ellis,

a cosmologist at the University of Cape Town in South Africa, describes as a “battle for the soul of physics”.

The rules of science have never been set in stone. What we know as the modern scientific method really blossomed in the 17th century, when a new breed of thinkers took the view that scientific knowledge can only come from first-hand observation. A classic example from this time is Isaac Newton's theory of gravity. Faced with the question of why the planets move as they do, Newton was apparently inspired by the sight of an apple falling from a tree. The planets orbit just so, he suggested, thanks to an attractive force between objects with mass – the same force that brought the apple to the ground. Once he had worked out the details, Newton was able to predict the positions of celestial objects.

False ideals

The theory was a great success, but could just as easily have failed. Indeed, Newton's predictions about the path of Uranus were off the mark. As it happened, that was down to an undiscovered planet – later revealed as Neptune – pulling it off course. But Newton's gravity was not consistent with another observation, that Mercury's orbit drifts slightly every year. Despite several claimed sightings, the planet invented to account for this wobble, Vulcan, never materialised. The problem was not solved until 1915, and this time the solution was a new and better theory of gravity. Einstein's theory of general relativity, which depicts gravity as the product of warped space-time, provided the tools with which he was able to correctly predict Mercury's peregrinations.

Newton's theory of gravity and its replacement were falsifiable – a term many people invoke when asked to define a scientific theory. In the 1930s, the philosopher Karl Popper tried to draw a line in the sand between science and hokum by contrasting Einstein's relativity with Sigmund Freud's psychoanalytic theory. Relativity made hard-and-fast predictions that, if refuted by observation or experiment, would signal the theory's failure. Freud's idea, on the other hand, was so elastic that it could stretch to fit pretty much any evidence. It was not falsifiable so, for Popper, it was not scientific. Simple.

"What happens when testing a prediction becomes impossible?"

Popper's principle has often been viewed idealistically, setting lofty standards that are rarely met. In the real world, science is not so neat and tidy. Scientists don't chuck out their theories when an experiment appears to refute them, although they have tended to accept the idea of making testable predictions. But what happens when testing a prediction becomes impossible?

In some cases we are already at that stage. Theoretical physicists have grown increasingly comfortable plucking theories out of thin air, shaping their visions of reality based on mathematical intuition rather than real-world observation. The Higgs boson is a case in point. In the 1960s, Peter Higgs, Francois Englert and Robert Brout

independently conceived of the mass-giving particle on a mathematical hunch. They were vindicated, if only belatedly and after huge wads of cash had been spent on the hunt, when the Higgs turned up at CERN's Large Hadron Collider in 2012. It was the crowning achievement of the standard model, the theoretical explanation based on quantum mechanics of how the fundamental particles and forces interact.

The problem is that the standard model doesn't have all the answers. We still don't know why matter and antimatter didn't wipe each other out at the birth of the universe, for instance. Nor does it give us much of a clue about the nature of dark matter, the elusive stuff thought to hold galaxies together. Yet theorists insist they should keep calling the shots even though their penchant for dreaming up beautiful solutions has hit an experimental impasse.

Take supersymmetry, the theory that every fundamental particle has a heavier superpartner. It was conceived as an elegant way to plug holes in the standard model. Alas, there is no sign of the particles it predicts at the LHC. Its proponents stubbornly insist that the evidence must lie beyond what we can presently see by smashing particles together under the French-Swiss border. We could keep building ever larger experiments, but producing collisions at the energies required to spot these superpartners might turn out to be beyond us. So if there is no prospect of testing it, is supersymmetry scientific?

The question has been raised more vocally of string theory, the idea that fundamental particles are not pointlike but tiny strings spanning several hidden dimensions, tucked

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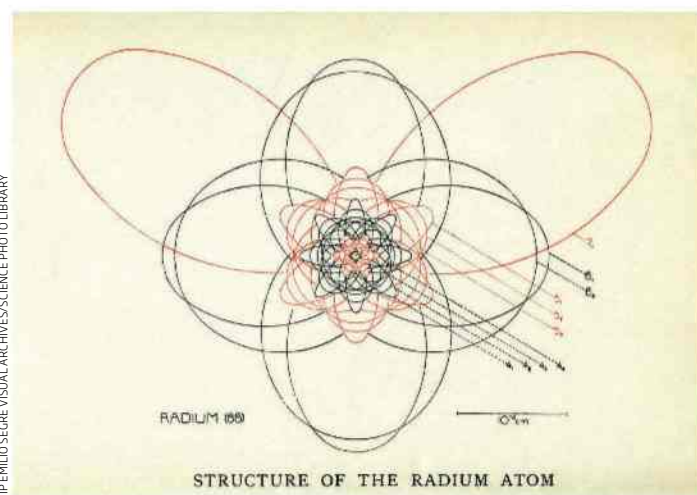
away in a tiny shape far too small to probe. String theory's supporters claim that it is the best way of unifying quantum mechanics and general relativity, the two pillars of modern physics, into a theory of everything.

It seems almost certain, however, that string theory can only be properly tested at energies beyond any conceivable experiment. So the theory has come in for plenty of flak. Peter Woit, a theorist at Columbia University in New York City, summed up the scorn in his 2007 book *Not Even Wrong*.

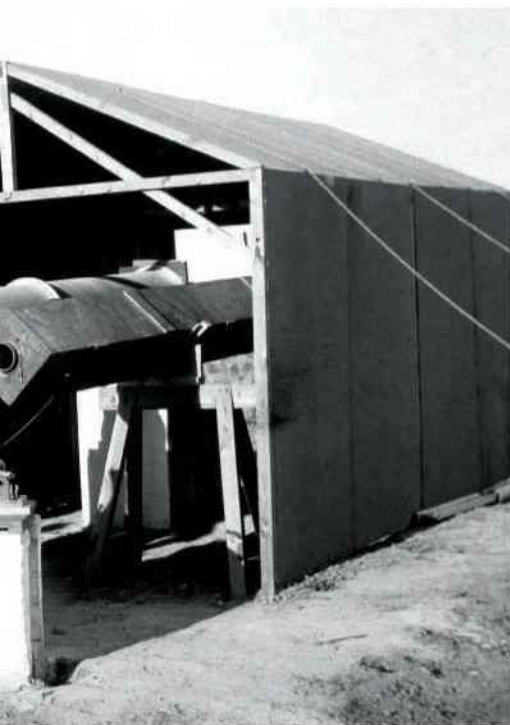
String enthusiasts are one source for the fresh riposte: if we can't hope to investigate the remaining secrets of reality with experiments in the foreseeable future, maybe we have to assess theories based on something else. Testing, they say, can wait.

This clarion call originally came from Richard Dawid, a theorist-turned-philosopher at the Ludwig Maximilian University in Munich, Germany. Dawid wanted to understand why string theorists are so wedded to their theory despite the glaring absence of empirical evidence. In a series of research papers and a 2013 book, *String Theory and the Scientific Method*, he set out the idea of "non-empirical theory confirmation" – that we can be confident we are on the right track by relying not on data or even mathematical beauty, but on two other considerations.

First is the TINA, or There Is No Alternative, criterion. If we are convinced that no other options exist for answering a given question – in string theory's case, how we can unify all four fundamental forces of nature – the chances are that this explanation is going to be



Some of our best descriptions of reality were once considered impossible to verify



See the light: squinting at a solar eclipse, this telescope validated Einstein's relativity

be a manifesto for a new way to do fundamental physics.

Their enthusiasm is far from universal, and some physicists are downright alarmed. Woit warns that the need for empirical vindication could be pushed so far into the background as to be invisible. Carlo Rovelli, a theorist at the University of Aix-Marseille in France, believes that this scenario has already come to pass. Rovelli is one of the founders of loop quantum gravity, a rival to string theory in attempting to reconcile relativity with quantum mechanics, and argues that the last thing we need is a system that legitimises failed theories. "A theory is interesting when it teaches us something new about the real world," he says. "Not when it becomes a house of cards that delivers nothing but university positions."

Matters came to a head last year, when Ellis and Joseph Silk, an astronomer at Johns Hopkins University in Baltimore, publicly declared that this trend towards "post-empirical science" – a term Dawid rejects as a "complete misrepresentation" – is a threat to the scientific method. If we lose sight of the need to anchor science in empirical data, they argue, we give a leg-up to creationists, homeopaths, anti-vaxxers and other peddlers of pseudoscientific nonsense. "We undermine the public's trust in science," says Ellis.

After a recent skirmish in the scientific journals, last December combatants from both sides gathered in Munich, at Dawid's invitation, to have it out in person. One who took Dawid's side was Nobel prizewinner David Gross at the University of California, Santa Barbara. He spoke of how Dawid had beautifully distilled the strategies physicists

"These are phenomena far beyond what we can reach with current experiments"

use to build confidence that a theory is worth pursuing, arguing that non-empirical assessment has always been part of the scientific method.

Popper himself recognised that theories should be falsifiable "in principle", leaving the door ajar for predictions that might become testable in future. And there are some weighty precedents to suggest patience might be prudent. Take atomic theory, which proposed that matter is composed of discrete units called atoms. When it was formulated in the

19th century, many physicists felt it would never be empirically confirmed.

General relativity is another example. Einstein came up with his theory based on an instinct for how the world should work rather than empirical data. Straight away it accounted for Mercury's wobble, and four years later the astronomer Arthur Eddington measured the sun bending the light reaching Earth from distant stars, just as the theory predicts. Still, it was not until the 1960s that we had the technology to test some of general relativity's other predictions, such as the gravitational redshift and time dilation. And only in the past month have we detected gravitational waves, the ripples in space-time created by colliding black holes and stars. In that sense, "string theorists are doing science as it has always been done," says Gross.

Out of reach

Unlike relativity, however, string theory and the multiverse have failed to make predictions that we can expect to test any time soon. Gross prefers to call string theory a "framework" rather than a theory, and it remains to be seen if it will ever be amenable to rigorous tests. In the meantime, proponents of these theories argue that we still need some way to figure out whether they are worth pursuing. Ellis, who also attended the Munich summit, points out that this amounts to theory assessment rather than validation – a distinction that is fundamentally important. For Ellis, experimental validation has to remain the ultimate goal, even if it is deferred for decades because we are dealing with phenomena at energy and distance scales far beyond what we can reach with current experiments.

Where do we go from here? Have we reached the point at which physics should abandon string theory and the multiverse? Or now that theorists are groping around in realms we cannot probe, should we accept that we have little choice but to persist with untested theories so long as they tick other boxes?

For physicists tasked with exposing the last remaining secrets of reality, such questions amount to an existential crisis. The chances of resolving it any time soon are about as good as the prospects for proving the existence of tiny oscillating strings tucked away in different dimensions. Even so, we can be sure of one thing: they will keep trying. ■

Jim Baggott is the author of *Origins: The Scientific Story of Creation* (OUP, 2015). Daniel Cossins is a features editor at *New Scientist*

correct. The second criteria is that a theory connects with others that have been tested.

On this second point string theorists have taken heart from one particular connection, the AdS/CFT correspondence. Proposed in 1997, it links a string theory formulated in a special kind of space called anti-de Sitter space (AdS) with a type of quantum theory known as conformal field theory (CFT). This kind of connection matters because quantum field theory underlies the experimentally well-tested, if incomplete, standard model.

It's not just string theorists taking this approach. Also on board are champions of the multiverse, the theory that addresses the question of why our universe is fine-tuned for life by proposing that it is one of an infinite array of universes. Sean Carroll, a theorist at the California Institute of Technology in Pasadena and a leading advocate of the multiverse, insists that if anyone is being unscientific, it is those physicists who seek to enforce outmoded philosophical principles and impossibly high standards. "People support these theories because they offer the best chance of providing a useful account of the data we actually do collect here in our universe," he says.

For his part, Dawid does not shrink from the inevitable caveats. He readily admits that building trust in a theory is not the same as validating it. He also says that theories must retain the promise of experimental or observational confirmation, even if this demand is "pushed into the background" for the moment. Many string theorists and multiverse aficionados think his ideas could

A GOOD CRY

Turning on the waterworks could work to our advantage, if only we knew when, how and why, says **Sonia van Gilder Cooke**

BRITISH tennis player Andy Murray knows what it's like to be unpopular. Early in his career, his aloofness and volatility on the court left many with the impression that he was petulant, spoiled, even unpatriotic. Then came Wimbledon 2012, and a gruelling final against six-time champion Roger Federer. After Murray lost, he took the microphone to thank his fans. He quavered, tried to speak and stopped to wipe away tears. In that moment, Murray won over the British public. "It took me crying at Wimbledon," he later acknowledged.

But tears can have the opposite effect. In 1972, they were the undoing of US Democratic presidential hopeful Edmund Muskie. He was his party's front runner at first, but his campaign fell apart after he was accused of crying while addressing the press to defend his wife's reputation. He claimed the moisture on his face was melting snowflakes – the event took place outdoors in a blizzard – but to no avail. His image as the candidate of calm and reason was shattered.

That crying can change people's fates is beyond doubt; history is full of examples. But why tears can have such a far-reaching effect is not obvious. "If you compare tearful crying with other emotional expressions, very little is known," says psychologist Asmir Gracanin at the University of Rijeka, Croatia. What we do know is that emotional crying is downright weird. Many animals produce tears to protect their eyes, but humans alone cry out of feeling. And we cry not only when we're sad, but also when we're happy, overwhelmed, enraptured and in pain. Why do we do it? What are the benefits of blubbing? More pointedly, when should you keep a stiff upper lip, and when might it help to turn on the waterworks?

People have long puzzled over crying.

Aristotle purportedly viewed tears as an excretion like urine. "That they are of one nature is plain to the taste," he is reported to have said. Reflecting this idea, in the 1940s, American psychoanalyst Phyllis Greenacre suggested that female weeping was a symptom of penis envy – a way for a woman to imitate a man urinating. Less provocatively, Darwin concluded that, in addition to lubricating the eye, tears "serve as a relief to suffering", although he didn't explain exactly how.

The idea that crying is cathartic remains popular. But what does that even mean? For Freudians it suggests the release of pent-up emotions – the principle behind folk wisdom encouraging people to "let it out". Another interpretation is that crying rids the body of harmful chemicals, such as stress hormones, produced by emotional distress. This theory dates from the 1980s, when biochemist William Frey found that tears of emotion were richer in protein than non-emotional tears. But Ad Vingerhoets at Tilburg University in the Netherlands is dubious, having twice tried and failed to replicate this finding.

The myth of catharsis

Like other bodily fluids, tears tend to reflect the composition of the blood, he notes, but that doesn't mean their function is to purge the blood of certain substances. "We would never say that after having drooled, we feel better," he says. Besides, the average cry only produces around a millilitre of tears.

So why do many people say that crying makes them feel better? One possibility, says Gracanin, is that it's just that misery doesn't last for ever. Our mood improves by the ➤



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time we've finished crying, even if it's just returning to normal from rock bottom. There is also some evidence that crying relaxes the body by activating the parasympathetic nervous system, or by pumping up levels of oxytocin, the "cuddle hormone". Gracani is investigating these possibilities, but says that even if the effects are genuine, the reason we feel better may be something other than tears. "We still don't know," he says.

Could crying have another purpose? These days, most researchers believe its function is not physiological, but social. "If you cry, you send a signal that you need help," says Gracani.

At first glance, liquid dripping from the eyes is a strange signal of helplessness, but neuroscientist Robert Provine at the University of Maryland, Baltimore County, thinks he knows how it evolved. Many animals

became worth our while to shed tears over any hurt, physical or mental.

Still, why did the eyes become the channel for signalling distress, and not sweaty palms or pale lips? The eyes are perhaps the best clue we have to what others are thinking, Gracani points out, so we are predisposed to look at them. You can also generally count on eyes to be visible. "They are a quite nice place to put a signal, as opposed to some other body part," he says.

And what a signal: Martijn Balsters at Tilburg University has found that the presence of tears on sad faces that volunteers saw for just 50 milliseconds boosted feelings of sympathy, supportiveness and friendship towards the individual pictured. Tears also help us overcome feelings of revulsion. Dennis Kuester at Jacobs University in Bremen, Germany, showed people pictures of injured faces, with and without tears, and measured the action of the levator labii, a facial muscle closely associated with expressions of disgust. Faces with tears provoked less revulsion than ones without them. "Tears really show that someone is in need of support, of empathy, of help, and that you should approach that person, even if there are some signs of injury," says Kuester.

One reason crying affects us so strongly is that, as many actors know, it's hard to fake. "It is considered an 'honest' signal, which makes it really powerful," says Vingerhoets. Provine agrees. "The ability to shed and respond to tears of emotion is important in the evolution of empathy," he says. Tears, it could be argued, bring out the best in us.

We view tears more sympathetically in powerful people and those seen as having earned the right to cry (below)



"One reason crying affects us so strongly is that, as many actors know, it's hard to fake"

clean their eyes and reduce irritation by secreting tears from the lacrimal glands, above the outer corner of each eye. Provine believes that as humans evolved, tears acquired a second role. "If someone has injured their eye or is suffering from disease, others might comfort or assist them," he says. "And after that, the presence of tears emerged as a cue for caregiving." In other words, once crying started to elicit help from others, it

But it's also clear that our reactions to crying depend on a lot of factors, not least the sex of the person crying – although not necessarily in the way stereotypes might dictate. For example, psychologists Heather MacArthur and Stephanie Shields of Pennsylvania State University presented subjects with scenarios in which both men and women in the roles of nurse and firefighter broke down in tears while trying to help an injured person. The

A VERY PECULIAR PRACTICE

Look closely at crying, and you will see just how strange it is. For one thing, it encompasses two very different processes: vocal wailing and tearing.

Human babies excel at the former, and for good reason – bawling is a very effective way of getting attention from caregivers. For their first few weeks, babies don't even shed tears, because their tear glands are still developing. But as they grow, crying becomes less vocal and more tearful.

This could be an evolutionary adaptation, suggests Ad Vingerhoets at Tilburg University in the Netherlands. Wailing advertises vulnerability to everyone around,

including predators, so once a child can move around, it is wiser to use the more covert signal of tears.

Another puzzle is that we cry throughout our lives. Intriguing changes in crying behaviour seem to reflect its changing functions as we age. Around adolescence, we begin to cry less over physical pain and more over emotional pain. Many people also start to exhibit "moral crying", in reaction to acts of bravery, self-sacrifice and altruism. Why we do this is still a mystery.

Also mysterious is why, as we age, we increasingly shed tears over things that are positive. Robert Provine at the University of Maryland, Baltimore

County, has a suggestion. "Given that emotional tearing is recently evolved, it's a very crude estimate of emotional expression," he says. "We also produce tears when we yawn, when we sneeze, when we laugh, when we cough."

Another theory is that so-called tears of joy do not actually reflect happiness at all; events such as weddings and holidays are often bittersweet because they remind us of the passage of time and mortality. This may be why children usually do not cry out of happiness: they don't yet make the associations with sacrifice, loss and impermanence.

Then there's the question of why

some people cry more than others. In a recent review of research, Vingerhoets reported that neurotics and people who are highly empathic cry the most. The former use tears manipulatively – as do narcissists, psychopaths and tantrum-throwing toddlers. Sociopaths are thought most likely to cry fake or "crocodile" tears.

And, although boys and girls cry frequently until puberty, in Western cultures women cry at least twice as often as men. Men are culturally conditioned to restrain their tears, but there may be more to it than that. Studies in animals suggest the hormone testosterone might have a tear-suppressing effect.



participants were then asked to rate the masculinity of the person who cried and the acceptability of crying. The firefighters were generally considered more masculine, whatever their sex.

Given the popular association between femininity and emotional display, you might think that crying by those in the more stereotypically feminine role of nurse would be more acceptable. In fact, the researchers found the opposite. "The more masculine people perceived the crier to be, the more they thought their tears were appropriate to the situation," says MacArthur. "It didn't matter whether that firefighter was female or male."

Doing a stereotypically masculine job may give you more of a licence to cry, whatever your sex, but being female means you are more likely to be comforted when you cry. This may have an unexpected explanation rooted in how tears alter our looks. Kuester showed a series of computer-generated neutral faces of ambiguous gender to volunteers, asking them to rate how masculine or feminine these looked with and without tears. His hypothesis was that adding tears to faces would make them look more feminine, given that stereotypes link tears and femaleness.

To his surprise, male respondents thought that tears made faces look more masculine. In another experiment, using faces with a range

of ages, Kuester found that men perceived tears as making faces look younger. In light of these findings, he speculates that tears may help protect women from inappropriate male advances and aggression. "When a woman is crying, it suggests to the male that, OK, now this is not a sexual object, but someone who needs help," says Kuester.

Men may not be sending out the same signals when they cry and, in many cultures,



BACK PAGE IMAGES/REX/SHUTTERSTOCK

they are under pressure to suppress their emotions. But these may not be as strong or pervasive as we tend to think. MacArthur and Shields looked at crying in the domain of men's competitive sport and found that far from being a place of "manly" restraint, sport provides a safe arena for displays of feeling, including cheering, crying and hugging, among fans and players. In the sporting context, "emotion widely believed to be 'unmanly' is allowed", they write.

"Crying in men isn't just acceptable, sometimes it can be downright desirable"

What's more, crying in a man isn't just acceptable, sometimes it can be downright desirable. In another study, Shields and colleagues found that participants rated men who showed intense yet controlled emotion in a sad situation as more competent than those who showed no emotion at all. "Such displays convey that men are human, feeling beings," the researchers conclude. The finding doesn't surprise Thomas Dixon, director of the Centre for the History of the Emotions at Queen Mary University of London, and author of *Weeping Britannia*. This take on manliness has appeared time and again throughout history, he says. "People have argued that crying shows that you are not only strong and rational, but also feeling, and that that's the ultimate kind of masculinity."

Although crying is still full of mysteries (see "A very peculiar practice", far left), its benefits are becoming clearer. "Showing your vulnerability is sometimes very positive," says Vingerhoets. But tears must be used wisely. "How positively tears are viewed depends on what you're crying about – it has to be perceived as something important, and not your fault," says Shields.

How you cry is also crucial: welling up usually makes a better impression than open weeping. Ironically, the powerful are more often admired for their tears than the weak. "The individual who would be most sympathetically seen would be somebody who has earned the right to cry via status," says Shields. That might help explain why Murray has gone from being considered spoiled and petulant to a two-time winner of the BBC Sports Personality of the Year award. "Crying changes everything," says Provine. ■

Sonia van Gilder Cooke is based in London, UK

Let's talk about it

Arguments about the origins of language leave **Vyvyan Evans** questioning some big assumptions

Why Only Us: Language and evolution
by Robert C. Berwick and Noam
Chomsky, MIT Press, \$22.95/£15.95



WHEN the Linguistic Society of Paris was founded in 1873, it famously included in its constitution a prohibition against speculating on the

evolutionary origins of language. A few years later, the London Philological Society followed suit. This admonition against positing what, then, amounted to no more than “just so” stories held for well over a century.

In the last couple of decades, the situation has changed, and with good reason. Discoveries in archaeology, cognitive science, primate behaviour, dating of ancient DNA and computational modelling of how languages have evolved mean we can now do significantly better than merely speculate.

Against this backdrop, linguist Noam Chomsky has teamed up with Robert Berwick, a computer scientist. In *Why Only Us*, they address precisely the question of how language evolved. But at times it feels as if they are still given to speculation.

Chomsky's global reputation was established in the 1950s and 1960s, when relatively little was known about how children acquire language. Chomsky argued that language – by which he means grammar – can be likened to a mental organ. This “language faculty”, he claimed, provides any normally developing human infant with a genetically

determined blueprint for grammar. The idea was that, despite the differences between the world's 7000 or so spoken languages, they all operate on a common “universal grammar”.

Chomsky has been working on a simplified version of this universal grammar proposal. For early modern humans to have evolved language, the genetic leap that made it possible must have been as simple as possible. This he boiled down to the capacity for a relatively simple grammatical operation that he called Merge back in the early 1990s, which allows words to be combined.

In *Why Only Us*, Chomsky and Berwick argue that this pared-down version of universal grammar is what would have enabled early humans to make the evolutionary jump from

“It's quite a stretch to suggest that language didn't evolve to enable communication”

language-less creatures to the loquacious beings of the Upper Palaeolithic, some 40,000 years ago. This, in turn, would have resulted in the unheralded rich cultural explosion around that time, including cave art, jewellery and ritual burials.

Their argument goes like this. As our capability for grammar is genetically programmed, and as no other species has language, it stands to reason that language emerged fairly suddenly, in one fell swoop, because of a random mutation. This is what the authors refer to as the “gambler's-eye view” in contrast to a “gene's-eye

view” of evolution. The sudden appearance of language occurred perhaps no more than 80,000 years ago, just before modern humans engaged in an out-of-Africa dispersion.

But to be convinced by this, the reader has to swallow a number of sub-arguments that are debatable at best. For one thing, the authors presume the Chomskyan model of human language – that the rudiments of human grammar (or syntax) are unlearnable without an innate knowledge of grammar. Its position seems less reasonable today that it once did.

Developmental and cognitive psychologists now have a clearer sense of the ways in which conceptual and linguistic learning works.

A human infant seems to have a range of both primate and species-specific learning mechanisms and abilities that enable the acquisition of language. The emerging consensus is that language acquisition can occur without an innate blueprint for grammar.

Second, the authors make dubious assumptions about the evolutionary trajectory of language, and attempt to convince the reader that Darwinian theory breaks down when applied to language. The issue, they claim, is that no other species has language, and that the cognitive abilities of all extant species simply couldn't be scaled up to achieve the capability.

In short, as language exists only in our species, without precedent elsewhere, then it did not evolve from some simpler form of communication. Hence, it must have evolved fairly quickly and in



JOHN MACLEAN/MILLENNIUM IMAGES, UK

one discontinuous jump. As the hallmark of language is a simple, computational syntax-engine, then, so the argument goes, this sort of species-specific event is not at all improbable.

However, this ultimately paints *Homo sapiens*, a species no more than about 200,000 years old,



into a corner. Modern humans become an evolutionary curiosity, isolated from the 2.8-million-year evolutionary trajectory of the genus that led to us. It also amounts to a highly selective and partial presentation of the recent research literature.

Although Berwick and

Chomsky are dismissive, recent evidence points to Neanderthals, who died out around 30,000 years ago, as having been, more or less, our cognitive equals. Recent archaeological findings suggest that they possessed a material culture approaching that of late StoneAge humans. And they may

Did language originate for internal thought or communication?

have had the anatomy, acoustic facility and cognitive smarts that made language possible.

Moreover, there is clear evidence of interbreeding between Neanderthals and humans. The implication is obvious: both species must have had language. That being the case, this pushes the origins of spoken language back much further, perhaps even to half a million years ago.

In addition, research in primatology and animal behaviour suggests that some of the precursors for language do exist in other species, ranging from European starlings to chimpanzees – with the latter using a sophisticated gestural form of communication in the wild. In fact, gesture may well have been the medium that incubated language until ancestral humans evolved the full-blown capacity for it.

An influential, alternative view of the evolution of language is to take a bigger-picture perspective from the one that Berwick and Chomsky espouse. The alternative sees language as an evolutionary outcome of a shift in cognitive strategy among ancestral humans, fuelled by bipedalism, tool use and meat-eating.

This new biocultural niche required a different cognitive strategy to encourage greater cooperation between early humans. Building on the rudimentary social-interactional nous of other great apes, an instinct for cooperation does seem to have emerged in ancestral humans. And this would have inexorably led to complex communicative systems, of which language is the most complete example.

Ultimately, *Why Only Us* is something of a curiosity. It takes a reverse engineering perspective on the question of how language evolved. It asks, what would language evolution amount to if

the Chomskyan proposition of universal grammar were correct? The answer is language as a mutation that produces a phenotype well outside the range of variation previously existing in the population – a macromutation. This flies in the face of the scientific consensus. Indeed, the book attempts to make a virtue of disagreeing with almost everyone on how language evolved. To see language bucking the kind of gradual evolutionary change that Darwin proposed is surely a controversial perspective.

The reader is asked to swallow the following unlikely implication

“Gestures may have incubated language until humans evolved the full-blown capacity for it”

of their logic: language didn’t evolve for communication, but rather for internal thought. If language did evolve as a chance mutation, without precedent, then it first emerged in one individual. And what is the value of language as a communicative tool when there is no one else to talk to? Hence, the evolutionary advantage of language, once it emerged, must have been for something else: assisting thought.

But this conclusion seems unlikely. The structure and organisation of the world’s 7000 or so languages indicates that its primary function is for communication between individuals. It’s quite a stretch to suggest that language didn’t evolve to enable this sort of interpersonal interaction.

Ultimately, the reader is left with a paradox: the evolutionary view entailed by Chomsky’s stripped down, minimalistic universal grammar calls into question the very account of language Berwick and Chomsky attempt to provide us with. ■

Vyvyan Evans is professor of linguistics, Bangor University, UK. His latest book is *The Crucible of Language*

Count John Dee

This notorious magician warrants a place in science's history, says **Philip Ball**

Scholar, Courtier, Magician: The lost library of John Dee, Royal College of Physicians, London, until 29 July

"THE book of nature is written in the language of mathematics," claimed Galileo. His full argument is actually more complicated than this, but philosophers, scientists and historians have seized on his statement to characterise "true" science: no branch of natural philosophy could call itself a science until it had become mathematical. "There is only that much genuine science in any science, as it contains mathematics," asserted Immanuel Kant in the 18th century.

Physicist Steven Weinberg seems to agree. The birth of modern science in the "scientific revolution" of the 17th century was "the search for mathematically expressed impersonal laws that allow precise predictions of a wide range of phenomena", he writes in his book *To Explain the World: The discovery of modern science*.

Yet Galileo had the good fortune to work on mechanics and astronomy: problems that can be conveniently mathematicised. Even today this maths-based definition still doesn't accurately describe much of chemistry (for which reason Kant denied that it was science), biology, the earth sciences or medicine. There's not a single equation in Charles Darwin's *On the Origin of Species*.

One person who would have welcomed Galileo's statement, had he not lived half a century too

early to witness it, was the English scholar John Dee (1527-1608 or 1609). Yet Dee doesn't appear in most histories of science, and some of Galileo's champions might regard him with a degree of horror. Dee is more or less uncategorisable by today's standards. Some of his Tudor contemporaries might have considered him

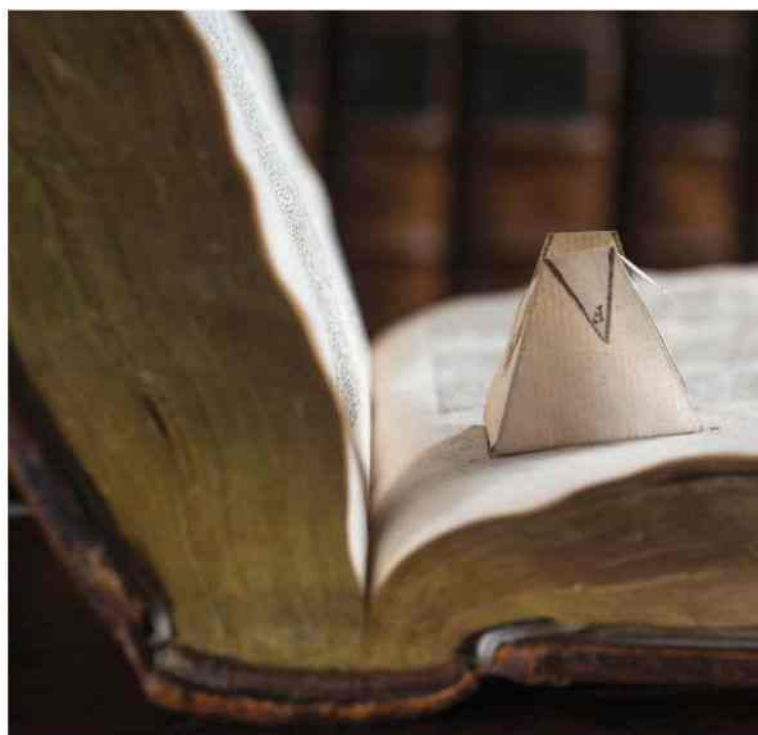
"Dee's work looks like mumbo-jumbo and mysticism. Yet it was mathematical"

a philosopher, an astrologer, perhaps even a magician – but they would have agreed that he was, above all, a mathematician.

And what did Dee do with maths? He cast horoscopes, practiced numerology and alchemy, and sought occult codes that would permit conversations with angels in the language used by Adam. Dee is, in short, the worst nightmare for those who want to tell the history of science



John Dee applied sophisticated mathematics to his study of angels



along the same lines as Weinberg. To them, Dee's work looks like mumbo-jumbo, superstition and mysticism. Yet it was fundamentally mathematical.

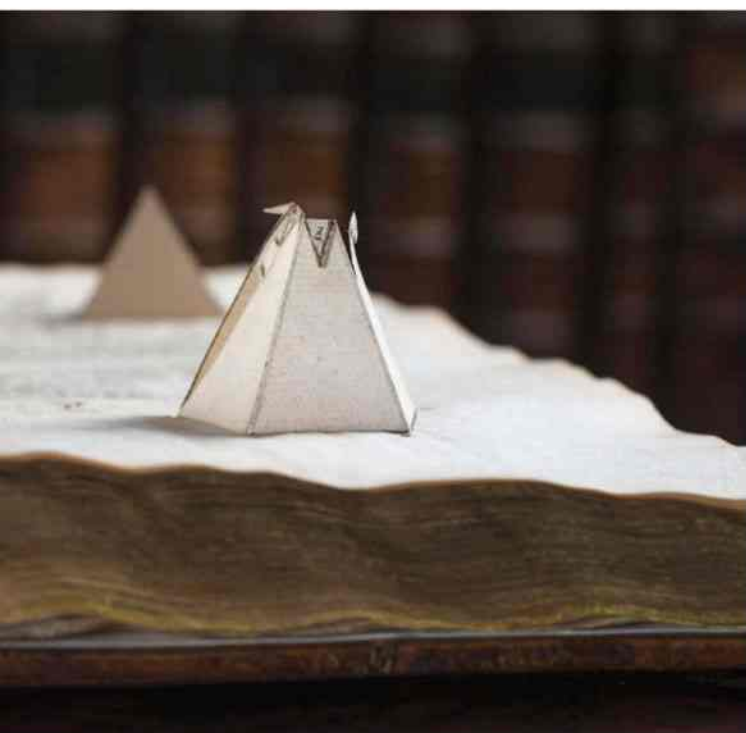
Dee's eclectic interests are explored in an exhibition of his books at the Royal College of Physicians in London. These books are a few pitiful remnants of the legendary library at his home in Mortlake, west of London, before many of its contents were pilfered while he was travelling abroad. (The apocryphal story has it that the library was ransacked and torched by a mob who suspected him of demonic witchcraft.)

Among the volumes on display is the first English translation of the influential mathematical treatise by the ancient Greek writer Euclid, here called *The Elements of Geometrie*, published in 1570 by Henry Billingsley, Lord Mayor of London. It's a gorgeous volume, with elaborate fold-out diagrams of polyhedra and intersecting planes, and Dee wrote the preface. That he was chosen for the task indicates the

esteem in which his mathematical expertise was held.

What's striking to modern readers about that essay is, first, that Dee considers it necessary to mount a defence of maths; and second, the breadth that he attributes to the discipline. Many people, Dee says, consider maths to be disreputable and allied with witchcraft. Indeed, some of the suspicion aroused by Nicolaus Copernicus's *De revolutionibus* in 1543 came not from his heliocentric theory of the solar system, but from the fact that he used maths to deduce what he could not directly see. In Tudor times, maths books were often burned on suspicion of being "conjuring books".

And maths really did have connections with the occult. Numerology was important to the Jewish mystical tradition called the Kabbalah, which Dee studied closely. Codes and cryptography were discussed in *Steganographia* (c. 1499) by the German abbot Trithemius, who was suspected of diabolical wizardry; it was this book that Dee examined



Towering figures: Euclid's *Elements* in a sumptuous edition from 1570

book called *Mathematical Magick*. The title might lead you to expect either a collection of “think-of-a-number” party tricks or a treatise on numerology. In fact, it was a textbook of mechanisms: levers, wheels, pulleys, screws, clocks, windmills – even submarines.

Dee personifies this natural-magic tradition. For some he was the archetypal Elizabethan magus, using a crystal ball with the help of his shady sidekick Edward Kelley to speak with angels or demons. It's possible that Shakespeare used Dee as the model for Prospero in *The Tempest*.

But the giants of the scientific revolution took him and his vision of mathematics seriously. Wilkins's *Mathematical Magick*, inspired by Dee's work, was one of the young Isaac Newton's favourite books, and Dee's preface was widely read throughout the 17th century. Robert Hooke defended Dee's angelic discourses when they were published posthumously, saying that they must be encrypted intelligence messages sent to the British court while Dee was abroad.

Dee prefigured 17th-century scholarly occultists such as the Englishman Robert Fludd and the German Jesuit Athanasius Kircher, who discerned mystical “hidden knowledge” in nature's workings while also exploring natural phenomena and mechanical inventions. If all this sounds a little like the mix we find in Isaac Newton too, you have got the right idea.

That's why Dee is a noteworthy figure in the history of science. And his example stands as a warning: that if we cherry-pick from the time when Renaissance magic was morphing into modern science, we will never understand what that extraordinary time was really all about. ■

Philip Ball is a science writer in the UK

to understand angelic communication. Even as late as 1651, Francis Bacon's friend and biographer John Rawley was accused of conjuring when he used geometry to calculate the height of a steeple.

This kind of accusation isn't fair, Dee argued. Maths is both useful and a source of hidden knowledge. He quotes the Italian Renaissance scholar Giovanni Pico della Mirandola: “By number, a way is had to the searching out and understanding of everything able to be known.” The wonders described in Dee's preface were so captivating that, according to historian Peter Zetterberg, many readers were probably “disappointed by the *Elements* itself with its pedestrian tone and topics”.

In particular, Dee says, maths is a practical discipline, useful for technologies such as hydraulics and surveying (geometry, he reminds us, means “land measuring”). It was also needed to make ingenious mechanisms, a popular art at the time.

Practically minded “virtuosi”

made their living by creating such devices for the princes and nobles of Europe, and Dee himself was said to have made a giant mechanical beetle for a play at Trinity College in Cambridge that astonished audiences. “And for these, and suchlike marvellous arts and feats naturally, mathematically and mechanically wrought and contrived, ought any student and modest Christian philosopher be counted and

“Copernicus aroused suspicion for using maths to deduce what he could not directly see”

called a conjurer?” Dee asked.

Mechanisms like this were considered in those days to be allied with the tradition called natural magic, in which the invisible forces of nature were harnessed to work wonders. In 1648, the Englishman John Wilkins, Warden of Wadham College in Oxford – where he convened the group of philosophers who later became the Royal Society – published a

COMPETITION

Enter our real-to-reel competition

EVERY week we fill *New Scientist* with good ideas, extraordinary stories, breaking news and different ways of looking at the world. We also keep an eye on how those stories develop. Some of them go nowhere. Others end up changing the way we live and think about our lives.

All very worthy.

The thing is, we find it very hard to stop working, and so it has come to our attention that remarkably few good scientific ideas ever end up in the movies we see. And that brings us to Culture Lab's latest competition. What scientific ideas do you think would make a good feature film?

We are teaming up again with SCI-FI-LONDON, the city's independent festival of science fiction films, to gather ideas for contestants at this year's 48-hour Film Challenge, the largest competition of its kind in the world, where teams are tasked with making a new and original short film, from concept to shooting, editing and delivery, all in the space of a weekend.

Will you help inspire a new generation of filmmakers to Hollywood greatness? Visit our competition page at bit.ly/WinningLines and, in just one sentence, describe the science fiction movie you want to see. All we ask is that there's a solid scientific idea in there somewhere – perhaps something you came across in *New Scientist*. The closing date is 18 March.

Six finalists will receive an invitation to this year's 48-hour Film Challenge awards ceremony in May. One winner will also win two tickets to New Scientist Live, our festival of ideas and discovery at London's ExCeL Centre, from 22 to 25 September. ■

The state of the job market in science

Are you pumped and raring to go on Monday mornings, or does the thought of heading back to work start to fill you with dread on Sunday? *New Scientist*, in association with specialist recruitment business SRG, has asked 4100 scientists, engineers, lecturers and other researchers how they feel about their jobs.

The survey respondents span a spectrum of ages, experience levels, qualifications and contract types. Over two-thirds describe themselves as scientists, while the rest self-identified as engineers, academics or as working on clinical trials. In the UK, 35 per cent of respondents had PhDs, while in other European countries and North America, that figure was over 50 per cent.

Their insight reveals how companies recruit, what employers and employees are looking for, and how much you can expect to earn in various sectors.

HOW DO SALARIES COMPARE?

Recent years have been turbulent for salaries in the various fields of science, and the trends for 2015 are mixed. In the UK, the average salary has dropped slightly, from £34,452 in 2014 to £34,384.

The outlook is sunnier elsewhere in Europe, where the average salary is up to €38,508 after two years of decline from 2012's high-water mark of €39,460, based on past surveys conducted by *New Scientist* and SRG. Countries that come in well above the mean include Germany (€46,019), the Netherlands (€51,579), Ireland (€51,667) and Switzerland (€99,737).

Wages in North America have risen marginally to \$75,757 from \$75,466, but are boosted by an average bonus of \$7,547, \$525 up on last year's average bonus size. Bonuses in the UK, on the other hand, dropped almost £600 to £2,262 compared with last year.

It is no secret that industry jobs often offer bigger pay packets than those in academia, but UK scientists seem to be well compensated in

academia, while medical and government research positions pay well in North America (see "Average salary by sector", opposite).

One UK group that has seen a growth in pay this year is employees aged over 55, whose average salary increased from £48,543 to £51,542 in 2015. This could be because of efforts

"In areas where there's a skill shortage, like biometrics, there's an increase in salary"

to retain employees with experience and expertise.

Specialists in areas such as biometrics, regulation and certain fields of medical research can also command higher wages, says Kelly Morton, managing director of SRG. "In areas where there's a skill shortage, there's still an increase in salary," she says. "People are almost buying the talent at a premium."

WHAT MAKES PEOPLE HAPPY AT WORK?

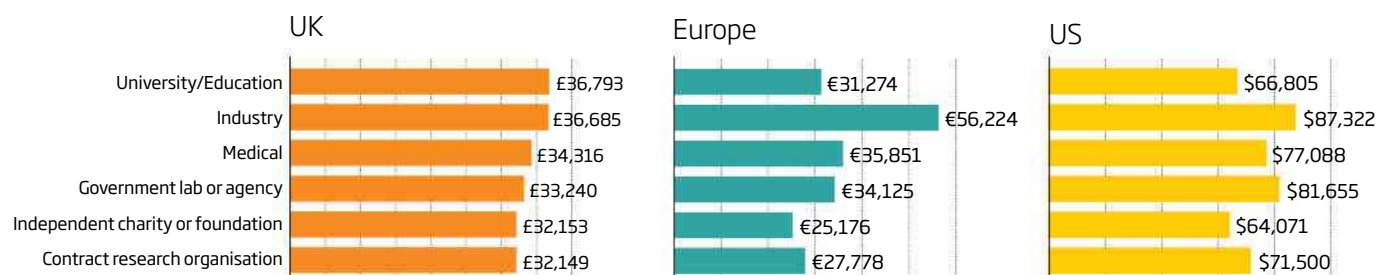
We all moan about work sometimes, and in many cases it might well be justified. In 2015, in the UK, 12 per cent of respondents rate their employers as "poor", whereas 7 per cent of respondents in North America dished out the same low rating.

More than half of respondents across all regions report that they find their job incredibly stressful, while well over a third say they do not have a good work/life balance. About a third of respondents said that they don't feel that the organisation values the work they do, and 86 per cent feel there is now more pressure on working scientists than ever before. The survey revealed that paid overtime is still relatively rare, with only 8 per cent of those working in mainland Europe and 23 per cent in the UK receiving this benefit. This is a key concern among employees in all areas, who list it as one of the most desired benefits an employer can offer.

Companies are starting to shift, however, in

Average salary by sector

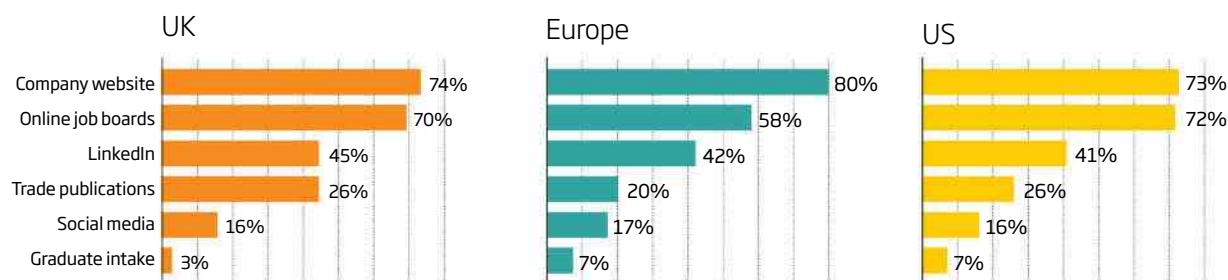
Our survey showed that those with academic positions earned relatively more in the UK than in the rest of Europe or North America in 2015, while industry and medical roles are big earners across the board



SOURCE: NEWS SCIENTIST/SRG

How companies recruit

Most companies in 2015 were recruiting via their own web sites and online job boards. While it is important to keep an eye on such sites it's also worth keeping a polished LinkedIn profile if you want to impress



SOURCE: NEWS SCIENTIST/SRG

HOW TO FIND YOUR PERFECT JOB

order to attract top talent. "Employers are beginning to realise that providing wellness and motivation not just for the employees, but for contractors, can be a mechanism to attract the best," says Jon Andrews, the UK leader of PWC's Human Resources Consulting practice.

Small-to-medium-sized companies are

"Employers are starting to realise that wellness can attract the best talent"

becoming more popular as places to work. About a third of respondents said they would prefer to work for a smaller organisation, while a quarter or less named a large company as their top choice. Large companies offer less stability than they used to, while smaller companies can offer candidates the chance to focus more on innovation and research, says Kelly Morton of SRG.

Looking for a new role? Get networking. Our survey found that about a third of employers use referrals from their own employees for recruiting. Companies in Europe and North America list this as their most effective way of recruiting, while in the UK, it's second only to direct hiring by company HR for effectiveness.

Successful networking is more than collecting business cards and making LinkedIn connections, says Lisa Balbes, a science career development consultant and author of *Nontraditional Careers for Chemists*. "It's talking to people and finding out what their company is looking for, and what's happening in their industry."

More than 40 per cent of companies now recruit directly on LinkedIn, and about one in five search for candidates on social media. So make sure your profiles are up-to-date, accurate and complete, says Balbes.

Get to know the company before applying. Most companies recruit via their own websites

(see "How companies recruit", above). "You need to be passionate about the work the company is doing," says Suzanne Lovell, director of HR at Heptares, a UK biotech firm.

Shareholder reports can give insight into the strategy of publicly listed firms, says Balbes. And social media can help you get to grips with a company's culture. Balbes recommends searching for pictures of the company's headquarters on Instagram. "If you're going in there for an interview, you can find out what the people dress like," she says.

Standout applicants are good all-rounders, says Carl Johan Sundberg at the Karolinska Institute in Sweden. Learn how businesses work, and how to lead teams, he says.

Survey carried out in association with SRG, a market leading resourcing company dedicated to the supply of scientific, clinical and engineering professionals across the scientific-based industries



Postdoctoral/Research Assistant Professor Position

Postdoctoral/Research Assistant Professor position is available immediately at the University of South Carolina (USC) for an extremely motivated researcher to study the role of urinary bladder smooth muscle ion channels (K⁺ and TRP channels) and their regulatory mechanisms. Applicants should have a PhD degree with a strong background in physiology, pharmacology, electrophysiology (patch-clamp and/or sharp microelectrodes), cell and molecular biology, bladder cystometry, and experience in animal handling and rodent surgery. A good background in urinary bladder smooth muscle function and regulation is strongly required. Applicants should be very skillful in setting up, care and use of laboratory equipment and have ability to develop new and improved methodology. Good communication and organizational skills, and excellent knowledge of English (both oral and written) are required. Applicants should have demonstrated scientific productivity, have a strong publication record, be able to design and execute scientific experiments independently, write manuscripts, prepare and submit competitive fellowship applications, and assist with grant writing. Team player spirit and a dedicated attitude toward scientific progress are an absolute must. Exceptional candidates with over several years of prior postdoctoral experience and stellar publication record in high impact journals may be considered at the level of research assistant professor. Please send a CV, letter of interest explaining relevant work experience, statement of research interests and career goals, and contact information for 3-5 referees to:

Georgi V. Petkov, PhD
Professor of Pharmacology
Department of Drug Discovery and Biomedical Sciences
College of Pharmacy, University of South Carolina
Coker Life Sciences Building, Room 609D
715 Sumter Street
Columbia, SC 29208
Phone (Office): 803-777-1891
Phone (Lab): 803-777-6216
Fax: 803-777-8356
E-mail: petkov@cop.sc.edu



In only 150 characters:
Postdoctoral/Research Assistant Professor position is available at USC to study the role of urinary bladder smooth muscle ion channels (K⁺ and TRP).



**National Institute
on Aging**
Intramural Research Program

Department of Health and Human Services National Institutes of Health National Institute on Aging

The National Institute on Aging (NIA), a major research component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), is recruiting for a postdoctoral position in The Section on DNA Helicases, Laboratory of Molecular Gerontology. The focus of the Section is to investigate the functions of DNA helicases in pathways that are important for maintenance of genomic stability and prevent symptoms of accelerated aging or cancer. Genetic and biochemical approaches are used to characterize the roles of helicases in cellular DNA metabolism and the mechanisms of unwinding by human DNA helicases. Small molecule and RNA interference screens, as well as model eukaryotic systems, are being used to investigate the roles of disease relevant helicases in DNA repair and replication stress response pathways.

Interested candidates must have a Ph.D. or M.D. with less than five years of postdoctoral experience and research experience in molecular biology, and training in mammalian cell culture techniques. Salary is commensurate with experience and accomplishments. Submit letter of interest, curriculum vitae, and references to:

Robert M. Brosh, Jr., Ph.D., Senior Investigator NIA-NIH,
Laboratory of Molecular Gerontology,
251 Bayview Blvd., Suite 100, Baltimore, MD 21224 USA.

Phone: 410-558-8578, or E-mail: BroshR@mail.nih.gov

For additional information on this position, visit
<http://www.grc.nia.nih.gov/branches/lmg/rbrosh.htm>

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The University of Michigan Medical School Postdoc Preview will introduce graduate students in the biomedical sciences to the extensive research and training opportunities at Michigan. During a fully-funded visit, recruits will interview with prospective mentors and network with current postdocs.

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Applicants must be U.S. citizens, permanent residents or currently enrolled in a U.S. graduate institution.

Research Areas:

Bioinformatics	Human Genetics
Biological Chemistry	Immunology
Biophysics	Microbiology
Cancer Biology	Molecular Pathology
Cell Biology	Molecular Physiology
Computational Biology	Neuroscience
Developmental Biology	Pharmacology



Faculty Position in Structural Biology and Drug Discovery

The Greehey Children's Cancer Research Institute (GCCRI) and Department of Biochemistry, School of Medicine of The University of Texas Health Science Center at San Antonio (UTHSCSA) are jointly seeking outstanding candidates (Ph.D., M.D., or M.D., Ph.D.) for tenure-track or tenured positions at the Assistant/Associate/Full Professor with expertise in structural biology (NMR, X-ray crystallography) to join the Pediatric Drug Discovery Initiative (PDDI). The PDDI will bring together experimental scientists in the fields of biochemistry and biophysics, biology, chemistry and computational science, as well as harness the unique established Centers, Institutes and Cores assembled at UTHSCSA to facilitate bench-bedside drug discovery and development. These include the Center for Innovative Drug Discovery, the Institute for Drug Development and the Integrated Cores for Macromolecular Structure and Interactions [including Nuclear Magnetic Resonance Spectroscopy (NMR), X-ray crystallography, Surface Plasmon Resonance (SPR), Isothermal Calorimetry (ITC), and Analytical Ultracentrifugation].

Applicants must have high quality peer-reviewed publications and evidence of independent research. Applicants should also have competitive funding if applying for Associate or Full Professor. The positions offer significant scientific resources, attractive start-up support packages and the potential for competing for additional state funds. Successful applicants will join a multidisciplinary team of researchers at the GCCRI and will be expected to develop collaborative programs and serve as mentors for students and research fellows, and, in some cases, junior faculty.

The Greehey Children's Cancer Research Institute is a unique specialized cancer research center focusing on basic and translational research in childhood cancer, and is housed in a state-of-the-art 100,000 sq. foot research facility on the Greehey Academic and Research Campus of UTHSCSA and supported by an endowment from the tobacco settlement from the State of Texas [<http://ccri.uthscsa.edu>].

San Antonio is the nation's seventh largest city and offers a rich, multi-cultural community with a thriving bioscience industry and is located at the edge of the beautiful Texas Hill County.

All faculty appointment are designated as security sensitive positions. The University of Texas Health Science Center at San Antonio is an Equal Employment Opportunity/Affirmative Action Employer including protected veterans and persons with disabilities.

Interested candidates should send curriculum vitae, statement of research interests including relevance to pediatric cancers and names of three professional references to:

Peter J. Houghton, Ph.D. Search Committee Chair
Professor of Molecular Medicine
Director, GCCRI
University of Texas Health Science Center at San Antonio,
7703 Floyd Curl Drive, San Antonio, Texas 78229.
Email: aguilarv@uthscsa.edu



Assistant Professor/Research Faculty in Bioinformatics

Candidates are invited to apply for this faculty position in the Department of Epidemiology and Biostatistics at the University of Texas Health Science Center at San Antonio. A research faculty position is available at the rank of assistant professor level.

SUMMARY

This position of bioinformatics faculty with a primary appointment in the Department of Epidemiology and Biostatistics (DEB) at the University of Texas Health Science Center at San Antonio (UTHSCSA) School of Medicine, will have overall responsibility for strengthening our collaborative research and direct a competitive bioinformatics service program. The candidate will apply bioinformatics techniques to analyze the next-generation sequencing, microarrays and other high-throughput profiling data to gain insights into the biology of diverse organisms with an emphasis on cancer research. Candidate will also manage a service component of our next-generation sequencing facility. The bioinformatics faculty will promote the development of interdisciplinary bioinformatics research in translational, clinical and community settings, and provide oversight and guidance to research staff and post-graduate student to conduct independent research.

The successful candidate will join an energetic team of researchers in the Department of Epidemiology and Biostatistics and the Greehey Children's Cancer Research Institute (GCCRI). The interdisciplinary environment of DEB and GCCRI is ideal for quantitative science, statistical, and bioinformatics advances for an early career research faculty. GCCRI is part of the Cancer Therapy and Research Center, an NCI-designated Cancer Center at South Texas that facilitates interdisciplinary research and breakthrough discoveries to advance human health. The next-generation sequencing facility and computational research facility at GCCRI has become a hub of collaborative research at UTHSCSA.

RESPONSIBILITIES

Perform a combination, but not necessarily all, of the following duties:

- Direct the bioinformatics research program for the next-generation genome sequencing facility;
- Provide management for bioinformatics services and collaborations within UTHSCSA, regional and national bioinformatics efforts and initiatives;
- Analyze genome-wide high-throughput data, such as data from gene expression, DNA mutation, and epigenetics studies;
- Provide and develop educational contents for the next-generation sequencing techniques in cancer and medical applications;
- Pursue the development or adoption of new bioinformatics technologies in areas such as basic research, cancer research, and clinical/translational research;
- Participate in extramurally-funded research in bioinformatics; provide planning, management and consultation to bioinformatics-related collaborative research programs and proposals;

EDUCATIONAL EXPERIENCE

Candidates must have a PhD in Computational Biology, Bioinformatics, Biostatistics, Electrical Engineering, Computer Science, or a closely related discipline. Preference will be given to candidates with a PhD and 2-year post doctoral experience in bioinformatics and next-generation sequencing data analysis.

KNOWLEDGE, SKILLS, AND ABILITIES

Candidate must have a minimum of one year of post-doctoral research or equivalent experience in an academic setting. A successful candidate is expected to have broad experience in next-generation sequencing data analysis spanning gene discovery, gene expression and regulation, sequence alignment, and homology detection, with scientific achievement demonstrated by journal publications, preferably with a focus on genome-wide profiling analysis, and proficiency in R, MATLAB, or Perl/Python programming in a Linux environment. Candidate shall demonstrate excellent communication skills, the ability to perform self-directed bioinformatics research, and excellent collaborative skills with unrelenting enthusiasm for genomic science. Strong preference will be given to candidates with experience in obtaining extramural funding in the computational biology and bioinformatics area.

WORKING CONDITIONS

Work is performed in an office environment. The position requires occasional travel to attend professional and grant meetings, as well as meetings for the University of Texas System.

Applicants should submit curriculum vitae, at least three letters of reference, and a letter describing their background, research interests, and relevant experience to:

Elizabeth A. Rolling
Project Coordinator
Attn.: Bioinformatics Position
Department of Epidemiology and Biostatistics
The University of Texas Health Science Center at San Antonio
7703 Floyd Curl, MSC 7933
San Antonio, Texas 78229-3900
rolling@uthscsa.edu

All faculty appointments are designated as security sensitive positions. The University of Texas Health Science Center at San Antonio is an Equal Employment Opportunity/Affirmative Action Employer including protected veterans and persons with disabilities.

Science Program Leader

National Eye Institute



The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

Are you an experienced Scientific Administrator in search of an exciting career opportunity? We may be the right place for you. The NEI at the NIH is seeking an exceptional Scientific Administrator to serve as a Science Program Leader. The Science Program Leader reports to the Director, NEI and will have a broad sphere of responsibility that includes the development and articulation of scientific priorities and goals of NEI; authority to speak on behalf of NEI regarding scientific program issues related to mission-specific NEI or trans-NIH programs; authority to speak on behalf of the NEI Director and demand the effective cultivation of collaborative professional internal/external relationships. As a senior program leader, the Science Program Leader in this category also provides authoritative leadership and supervision through the assignment of significant Institute equivalent resources (internal and external), and integrative management of portfolios involving a broad range of scientific, clinical, regulatory, manufacturing, and intellectual property issues.

The Science Program Leader will have responsibility of providing guidance and leadership in translating nonclinical findings to clinical testing. This incorporates a large and broad arena of expertise and capabilities including: (1) a strong fundamental background in basic science research to generate a compelling data package to convince the FDA and other regulatory agencies (internal and external) to advance an investigational agent to human testing (2) a comprehension of the regulatory requirements to plan, design, execute, interpret, and report Good Laboratory Practice (GLP)-compliant toxicology studies; (3) the knowledge required to assure a well-written and appropriately designed clinical protocol; (4) to ensure high quality synthesis, production, and testing of clinical grade material for Phase I testing in compliance with FDA gene therapy regulations; (5) operational skillset to work with individuals of diverse backgrounds including scientists, engineers, clinicians, pharmacists, individuals with legal and regulatory expertise internal and external; (6) ability to define, manage, and implement

plans/programs to attain goals on time; and (7) experience in working with biologics and the Center of Biologics Evaluation and Research (CBER) division of the FDA.

QUALIFICATIONS REQUIRED: Candidates must have a Ph.D. in Biophysics, physiology, or related discipline and a minimum of 15 years of experience in preclinical drug development. Experience with gene therapy for ocular diseases or biologics is a must. The incumbent must have demonstrated leadership and project/program management skills as evidenced by planning, developing and managing a complex research program. In addition, experience interacting effectively with representatives of other government agencies including FDA, universities, other research institutions and organizations, advocacy groups, and representatives of the pharmaceutical and biotechnology industry is a must, as well as the ability to work in an environment of considerable political visibility, controversy, and pressure. Lastly, the Science Program Leader must have strong communications skills, both oral and written on medical research issues for diverse audiences; excellent analytical, organizational and time management skills; and a high degree of initiative and resourcefulness as assigned projects may have little or no precedent. This position will be filled under a Title 42(f) excepted service appointment.

SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of Federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

HOW TO APPLY: Submit a current curriculum vitae, bibliography, and full contact details for three references. In addition, applicants are asked to prepare a statement that addresses the specific qualification requirements (please limit the statement to no more than two pages). Send application package to Cynthia Best at bestc@nei.nih.gov.

NEI will begin accepting applications February 15, 2016 and plans to have the position open for 30 days.

Information about NEI can be found at NEI.NIH.GOV

You may contact Cynthia Best with questions and for more information about this vacancy on (301) 496-2234.

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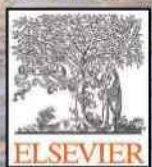
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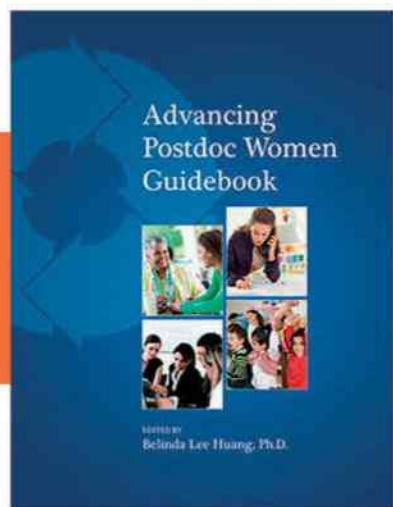


Regulatory Pharmaceutical Analysis Program
OFFICE OF REGULATORY AFFAIRS (ORA)

The **FDA's Office of Regulatory Affairs** is seeking PhD-level scientists with experience in chemical analysis of complex pharmaceutical products to work at one of ORA's field laboratories located in Jamaica, NY or Irvine, CA.

Candidate must have a PhD in a mainstream technical field such as chemistry, biochemistry, physics; must have extensive experience in the analysis/characterization of complex pharmaceuticals such as protein-based or nanotechnology drugs; and must have expertise either in mass spectrometry or NMR spectroscopy. Must be able to independently execute defined projects, develop new methods to meet agency needs, and serve as an expert in area of specialty. Must possess excellent written and oral skills. Must be able to engage with other experts in industry, academia, other parts of FDA, other federal state/local agencies; establish collaborations when necessary; and represent ORA in field of expertise.

Salary range: **\$75,000 – \$120,000** per year and will be commensurate with experience. Interested persons can send curriculum vitae or resume to: **ORSjobsearch@fda.hhs.gov**



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2016 Postdoctoral Preparation Institute: Career Transitions

Advancing Biomedical Research Workforce Diversity

June 2-3, 2016

Bethesda North Marriott Hotel &
Conference Center, Bethesda, MD



■ Who Should Attend:

The program is primarily intended for postdoctoral fellows who are near completion of their postdoctoral training appointments.

■ Institute Dates:

June 2-3, 2016

■ Location:

Bethesda North Marriott Hotel &
Conference Center, Bethesda, MD

■ Hotel Reservation Deadline Date:

May 11, 2016

■ Travel Awards are Available:

The FASEB Office of Sponsored Programs, Diversity and Grants Administration is currently accepting travel award applications to help support participation in this two-day career development program.

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Important Deadline

Registration/Travel Award
Application receipt deadline:

■ Friday, May 6, 2016, at 5PM EDT

Travel awards will be provided for all eligible applicants (those not receiving federal funding and meeting other criteria e.g., citizenship/residency status) who are approved and selected to participate in the Institute. The maximum amount for the travel award is \$1,250.

NOTE: We are not allowed to provide travel awards for selected participants who reside within a 50-mile radius of the meeting venue in Bethesda, MD.

The 2016 Postdoctoral Preparation Institute is funded by a grant from the National Institute of General Medical Sciences of the National Institutes of Health (T36-GM008637-20); therefore, travel awards are restricted to USA citizens or legal permanent residents of the USA, who also reside within the USA or USA territories.

For more information and application forms: twdprograms.org



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EDITOR'S PICK



Hope for those with anosmia

From Geof Butterwick

Jessica Wapner discussed the potential benefits for those with an impaired sense of taste of creating new smells and flavours (6 February, p 39). I was surprised at the scant mention of the implications for those of us with olfactory disorders.

Since an accident in my youth, I have experienced hyposmia – a decreased ability to smell. Recently I discovered that I have anosmia: a complete loss of sense of smell. Doctors ruled out obstruction and, thankfully, a brain tumour as causes, concluding that it is due to a damaged olfactory nerve, for which they can offer no treatment. My inability to smell fresh fruit, wine or cheeses is a disadvantage. Compared with our sense of smell, our taste buds play only a small part in the way we perceive flavour.

Anosmia and hyposmia affect 4 million people in the US alone. I hope the research will provide some relief for us too.

Woodbridge, Suffolk, UK

Mick O'Hare writes:

■ As *New Scientist's* resident anosmic I am well aware that olfactory disorders are often considered trivial compared to loss of other senses. But they affect a quarter of adults over 60. I described my experience as “The unbearable absence of smelling” (24 September 2005, p 42).

Geology, politics and nuclear waste

From Peter Ward

On his trip to Germany, Fred Pearce was given the dogma on nuclear waste (6 February, p 10). I have worked for 25 years at the Gorleben exploration mine, which is looking into storing such waste, and I chair the workers' committee there.

The picture of “20 swimming pools” of plutonium-bearing waste at Asse salt mine is emotive. The complete radioactive inventory there is 1/200th of that in a single flask of spent fuel from a nuclear power station, and less than that in the potash originally mined at the site.

There is no race to retrieve the nuclear waste from Asse before it is “flushed to the surface”. The most dramatic estimates predict a minimal release in 40,000 years.

In a 2011 study comparing the safety of retrieving the waste, leaving it where it is or putting it somewhere else in the mine, leaving the waste in the mine won on 4 of the 5 criteria considered. Practically all my colleagues agree that retrieving the waste from Asse is stupid, impractical and a waste of resources. But backfilling and closure is unacceptable to environmentalists, who will not accept a finished nuclear waste repository in Germany.

Gartow, Germany

From Bob Downie

Fred Pierce gives a timely reminder that no government has solved the two issues facing nuclear waste disposal. First, none has worked out the geological and technical criteria for safely storing waste for many millennia. There is also the political problem of persuading a local population that a nuclear waste repository will bring benefits to an area and be guaranteed not to leak.

The UK government has recently decided to build the first nuclear power station for a

generation, still with no answer to the ultimate questions of how the dangerous waste will be isolated from the biosphere.

Glasgow, UK

Driverless cars that move like trains

From Brett Porter

Anna Nowogrodzki reports that autonomous cars will only ease traffic when paired with smart traffic lights (23 January, p 21). There is the possibility that traffic lights may become redundant when all cars are autonomous. Traffic could flow continuously if the cars compared signals with each other, GPS and stationary traffic monitors.

Also, Stephen Shladover's claim that autonomous cars will not reduce the time it takes a vehicle stopped at a traffic light to start moving seems implausible. If all vehicles are autonomous, all in a queue will be able to start moving immediately the “go” signal is received, without the delays caused by drivers' reaction time or daydreaming. The cars will start moving at the same instant, like train carriages.

Burleigh Heads, Queensland, Australia

Brain takes time to exit habit mode

From Chas Bazeley

Teal Burrell gives a fascinating insight into the way the brain copes with forming habits (16 January, p 30). Observing my own and other drivers' behaviour on UK roads, I note that many appear to be on autopilot when driving at steady speed.

But if the routine is disrupted, for instance by a child running into the road, how long does it take to engage a different area of the brain and react?

Colchester, Essex, UK

A race to the Finnish

From David Holtum

James Witts describes how brain training could smash sporting world records (30 January, p 38) and Megan Scudellari how your language shapes your brain (6 February, p 26). I remember a Nordic friend telling me years ago about an ability that Finnish people had that enabled them to carry on when they were beyond what they could endure. It had a one-word name: “sisu”.

This has no straightforward English translation but it describes an internal force that encompasses strength of will, determination, courage and perseverance. The friend attributed the success of Finnish distance athletes such as Parvo Nurmi in part to this ability.

Bathampton, Somerset, UK

The gravity chirp danger zone

From Nathaniel Hellerstein

LIGO detected the gravitational waves from a black-hole merger (13 February, p 6). The energy released in gravitational radiation was equivalent to three solar masses. That's a lot of energy in a short chirp; a greater power output than all the stars in the universe. I was wondering how close your spaceship would have to be to the black holes for you to feel the chirp. Also, how close for the chirp to kill you.

San Francisco, US

Where is this 'global' browning?

From Montserrat Filella and

Juan Carlos Rodríguez-Murillo

The cover of your 9 January issue promises to tell us “what's muddying the world's waters”.

f “What if you don’t have the choice of taking an exam in the early morning?”

Jaquelyn Flores (20 February, p 18) on the suggestion “take exams early in the morning to get a higher score”

But, as the article (p 34) in fact reports, this “global browning” effect has been demonstrated only for North America and northern Europe – as we reported in the journal *Water* in May 2014 (doi.org/bcgs). In most of the rest of the world there simply isn’t enough data.
Geneva, Switzerland and Madrid, Spain

Hold states to account for slavery

From Jerry Hershberg
I agree with Kevin Bales that slavery is evil and destructive to the environment (6 February, p 24). But I am frustrated by the lack of details in his piece. He takes seafood processing camps in the Sundarbans World Heritage Site as an example. Is he referring to sites in Bangladesh or in India, where I understand slavery is even worse?

What kind of slavery is it? How many are there? Why aren’t states held responsible for allowing it?
Torrance, California, US

Concerned about menopause delay

From Janet Thompson
Clare Wilson describes procedures that could delay the onset of menopause (2 January, p 8). She mentions that it may “be possible to do this without continuing to have periods – endometrial ablation can be used to remove the lining of the womb”.

I was advised in May 2015 to have endometrial ablation at the same time as a minor operation to remove a polyp and fibroid. My periods stopped in September 2015. But since June I have had sharp pains in my lower abdomen, increasing in frequency and intensity. Now I have periods, accompanied by these pains.
Little Chalfont, Buckinghamshire, UK

Is lytigo-bodig a recent disease?

From Carol Stevenson
If lytigo-bodig is caused by the toxin BMAA in a staple food of the

Chamorro people in Guam, why is it relatively recently identified (23 January, p 14)? Is it possible that another food, now no longer eaten, was very high in serine, that seems to offer some protection from the disease?

This does seem possible on a remote island that has been taken over by an outside power.
London, UK

The editor writes:

■ Lytigo-bodig peaked in the 1950s. It has been suggested that around this time islanders gained increased access to firearms via US military bases, and used them to shoot BMAA-laden flying foxes for food. Also, the cycad seeds themselves began to be dried into chips or ground into flour and used in domestic dishes.

Many-eyed beasts of the deep

From Ian Wright
You described mineral eye lenses in the shells of some molluscs (28 November 2015, p 19). I raised

my eyebrows at the assertion that, because there were only a hundred or so light receptors behind the lenses, the creatures must see “pretty much just a blob”. Might their nervous systems (whatever form these take) combine information from all the eyes into one image?
Sheffield, UK

Remembering long-gone glaciers

From David Dare
Your article on tropical glaciers (30 January, p 10) took me back to my time surveying the snout of the San Pablin Glacier in Colombia in 1959. In recent years I have attempted to locate the glacier in photographs of the area and on Google Earth. The article explains why I have been unable to do so.

It should be noted that even 57 years ago there were some indications that the glacier was in retreat – the amount of pristine moraine and sand exposed below the glacier’s snout – although climate change as we now understand it was unknown to us.
Edinburgh, UK

For the record

- We contained an added E-number. Carboxymethylcellulose, an emulsifier, is E466 in the EU’s classification (13 February, p 12).
- The cartoon “science fighter” character whose special power is a “black hole blast” would, in most universes, be Stephen Hawking (Letters page, 13 February).

Letters should be sent to:
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Email: letters@newscientist.com

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A CITROËN car could move you in unexpected ways, discovers Chris Barrett. The manual for his new C3 Picasso informs him that the traction control featured in this model “keeps the vehicle on the trajectory required by the driver, within the limits of the laws of physics”.

“Presumably,” he says, “if I switch it off I can select a trajectory outside the laws of physics.” We’re eager to hear back from Chris, and discover where in the universe, multiverse or timeline his motoring trips have taken him.

RECENTLY Feedback pondered on manifestations of quantum superposition in everyday life (13 February). Ian Turnbull is prompted to ask “is the glass half-empty or is the glass half-full?”

“I have done a lot of experiments,” writes Ian, “which show that the state the glass collapses to is dependent upon the arrival of a third party influence.” Welcome guests make a glass half-empty, prompting you to ask for another as they head to the bar.

However, the arrival of someone you’d rather avoid makes the glass half-full, so you decline the offer. “Then while the third party pops off to the bar to buy a pint for themselves, very quickly the half-glass is consumed and you disappear,” explains Ian.

NEVER let a good crisis go to waste: before the ink was dry on their (roundly debunked) hypothesis that GM mosquitoes were to blame for Zika (20 February), *The Ecologist* was pursuing a new theory, that pesticides were responsible for the microcephaly associated with the virus.

Pyriproxyfen, an insecticide that inhibits the growth of mosquito larvae, has been added to water tanks in Brazil since 2014. There is no evidence to suggest it causes birth defects – and plenty to demonstrate that it doesn’t, having been thoroughly tested in animals – but that didn’t stop *The Ecologist* republishing the claims.

Work is under way on a vaccine for Zika – if only one existed to prevent the spread of conspiracy theories.

MAYOR of London Boris Johnson fielded questions on Twitter earlier this month, prompting one member of the public to ask for his views on the recent discovery of gravitational waves (20 February, p 8). “A bit fishy that they detected this billion-year-old collision of two black holes just when they switched it on,” the mayor replied.

As one wag was quick to point out: “They were hardly likely to find the evidence before they switched it on, were they?”

SAFETY first: on a recent order for a laminating machine, Peter Duffell couldn’t help but notice the guidance that “this machine needs to be used with a life jacket if cut up or small pieces of paper are being laminated”.

This seems unusual, though Feedback supposes that there is no better time to laminate all your small personal effects than when cast headlong into the sea.

GUIDELINES for the multiverse: Bruce Mardle’s pack of macaroons gives nutritional information on the contents, specified as “Per macaroon: $\pm 42g$ ”. Presumably, this information tells you not just the calories you will accrue by eating one, but how many calories the alternative version of you will forgo by abstaining.

HIGH specifications: those planning to spend a night at the Wood Norton Hotel in Worcestershire will be safe in the knowledge of not just which room they are heading towards, but which hair on the carpet.

Ralph Bowsfield spots an interesting detail on its website, which gives the location of the 19th-century manor in grid coordinates to 16 decimal places – a level of precision that directs us to the nearest picometre.

A TOUGH pill to swallow? Alaric Sanders writes to tell us that his father was prescribed some antibiotics to treat a prolonged illness. The pharmacist’s instructions tell his father to: “Take one tablet daily immediately after

food. Take on an empty stomach, at least half an hour before food or two hours after food.”

“Perhaps the new procedure for avoiding antibiotic resistance without disappointing antibiotic-craving patients is to give them the drugs, but confuse them into not taking the pills?” he suggests.

PREVIOUSLY Feedback discussed the value of things we’d be much happier not knowing (30 January), and what to call the chance arrival of these unwelcome facts on our computer screens. “Yuk hit?” retorts Neil Armstrong. “How about ‘gross encounters of the nerd kind?’”

FINALLY, while driving along more conventional geometries in the Devonshire resort of Dawlish, Adrian Wilkins came across a sign for a holiday park advertising, among its other leisure facilities, a “super heated pool”.

“I wonder whether they carried out a proper risk assessment,” ponders Adrian. Further online searches uncovered more



establishments offering a similar scalding experience, such as the Hotel Bonaventure in Montreal. “Should the unthinkable happen,” writes Adrian, “I can only assume the coroner would give the cause of death as ‘misadventure at the Bonaventure’.”

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week’s and past Feedbacks can be seen on our website.

A flyer sent in by David Prutchi reveals that patients seeking help for opiate dependence in New Jersey are currently being provided for by one Dr Hisham Hashish

Pinkies

I often find these strange, thumb-sized, pink globular blobs (see photo) just above the waterline along drainage ditches and canals in Borneo and Thailand. What are they? Over time they turn dusty white and fall away.

■ The blobs are the egg masses of apple snails from the Ampullariidae family. These freshwater animals have large, rounded shells, and are found in many tropical and subtropical areas. For example, the genus *Pila* occurs naturally in Africa and Malaysia, whereas *Pomacea* is found in the Americas.

The edible species *Pomacea canaliculata*, originally from South America, was introduced to Thailand in 1980 as a food source. Further introductions and dispersions elsewhere in the region, including that of the related golden apple snail (*Pomacea bridgesii*), have led to serious devastation of rice crops.

Pomacea females lay their eggs out of water. These are usually pigmented, so the photograph may show the eggs of one of these invasive species.

P. canaliculata females can spawn repeatedly without any new contact with males, meaning that populations can rise rapidly. The snails have a siphon for breathing in air and gills for aquatic respiration, so can crawl out of the water onto emerging vegetation or any available hard surface to lay their egg masses.



Once the offspring hatch, they drop into the water and the broken egg shells eventually disintegrate.

Peter Topley
President of the Conchological Society of Great Britain and Ireland,
Bedfordshire, UK

Windblown

Our local community turbine rotates at a constant speed of 39 revolutions per minute. What is the mechanism that allows greater power to be generated in strong winds, in terms I can explain to my grandchildren?

■ For good reasons, our electricity supply works not by providing a single, steady flow, but by flitting backwards and forwards. This is called alternating current, or AC for short. The electricity generated

by wind turbines must keep in time with this, so all of them rotate at the same speed. When the wind blows harder, adjustments inside the turbine make it harder to turn the rotors, generating more electricity with each rotation.

It is exactly like trying to pedal your bike at a continuous speed. When you leave the flat and start going uphill, it becomes much harder to maintain the same pedalling rate.

Tim Stevenson,
Great Missenden,
Buckinghamshire, UK

■ Older designs for wind turbines aim to keep the blades rotating at a constant speed because this enables optimal conversion of the movement into electrical energy for use in the national grid. Too slow and the turbine doesn't catch enough wind energy; too fast and the blades and other components suffer excessive stress. If left to itself, the turbine would spin faster as the wind increases, just like the plastic windmills we buy at the seaside.

We convert the wind into electricity by allowing the turbine to spin freely and then "braking" it to capture as much energy as possible. But instead of a mechanical brake such as those on a car or bicycle, which remove the energy from a spinning wheel, we use an electrical "brake" that allows us to capture energy and convert it into electricity rather than waste it as heat.

We don't want to stop the turbine completely, but allow it to turn at a constant speed regardless of how hard the wind is blowing.

If we want to freewheel a bicycle down a gentle hill at a steady speed, we apply the brakes gently and they warm up by the time we reach the bottom. If the hill becomes steeper, but we want to keep the same speed, we squeeze the brakes harder and they get even hotter because they convert more energy into heat (don't test this by touching the brakes).

Similarly, when we want our turbine to turn at 39 revolutions

"Older wind turbines rotate at a constant speed because it makes for easier conversion into electricity"

per minute in a steady breeze, we only apply a small amount of electrical braking, and generate a small amount of power as a result. When it's blowing a gale, we can really apply the "brakes" hard to get a lot more power out, even though the blades are spinning at the same rate.

Steve Agar
Hexham, Northumberland, UK

This week's question

JUST LION AROUND

If a lion was assessed under criteria for human health, would it be considered unfit?

Jeremy Smith
Plymouth, Devon, UK

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A black and white portrait of Professor Dame Carol Robinson, a woman with dark, shoulder-length hair, smiling slightly. She is wearing a dark V-neck top with a small brooch on the left side.

Professor Dame Carol Robinson

2015 Laureate for United Kingdom

By Brigitte Lacombe



Science needs women

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Dame Carol Robinson, Professor of Chemistry at Oxford University, invented a ground-breaking method for studying how membrane proteins function, which play a critical role in the human body.

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